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Designing Product-Service System solutions for value co-creation: Integrating Product-Service Systems and Service Design approaches

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TO MY FAMILY

ABSTRACT

The rapid advance of technology is changing society at a very fast pace, bringing change to the nature of product and service (e.g. smart-products). Customers are more informed and have access to more resources to fulfil their needs. In this context, product and service providers alike, look for new approaches to create more complete solutions for their customers. Acknowledging the limitations of physical products to stay relevant in current markets, manufacturing companies are infusing service in their offerings. Likewise, service providers need more support to combine multiple touchpoints with their customers in a cohesive way to enable positive customer experiences.

Different ways to conceptualize service and create new solutions exist. On the one hand, Product-Service System approach integrates product and service components as well as organizational network components, to create integrated offerings. On the other hand, Service Design looks at customer experiences from a holistic perspective and envision innovative ways to support value co-creation processes with customers and other stakeholders. Although complementary, these approaches have yet to be integrated. Bringing together PSS and Service Design complementarities can support companies to co-create new product-service system solutions, to evolve their design processes, and to improve their business positioning.

This thesis investigates how PSS and Service Design can be combined to better support the design of integrated product-service system solutions that enhance value co-creation processes, within multiple design contexts. To address these challenges, the research objectives are three folded: (1) Explore overlaps and complementarities between PSS and Service Design to create a conceptual framework; (2) Develop an integrative PSS approach, which combines PSS and service design, and the respective design models to design product-service system solutions from an integrated perspective, since the exploration stage to the development of mock-ups and prototypes; (3) Understand how PSS can be incorporated with Product Design and Service Design to enrich these approaches.

Following a Design Research approach, the objectives led to three contributions. Study (1) analyzes overlaps and complementarities of PSS and Service Design approaches through the lenses of S-D Logic, based on literature review, and develops a conceptual framework. The framework creates a unifying language, outlining potential synergies between PSS design and service design by exploring the concept of value co-creation; and supports the development of future research that lays at the intersection these areas. Study (2) presents the development of a new integrative PSS approach and models. It integrates the co-creative and human-centered approach of Service Design with the organizational-oriented perspective of PSS, throughout the different stages of the design process through a design research approach. It validates this approach through a case study in a laboratory equipment company to design new integrated solutions, which have resulted in prototypes that were partially implemented. Study (3) advances the previous contributions by exploring complementarities and gaps of product design and service design, which remain important backbones of current manufacturing and service companies. The study also explores how PSS approach can enrich these design approaches. A multiple case study with projects using a product design approach and service design approach, in collaboration with companies was undertaken to support the research.

The thesis contributes to advance PSS design research incorporating the complementary perspectives of PSS and service design which were not previously integrated. Moreover, it contributes with a new method to support the design of integrated good-service solutions for value co-creation, and contributes to understand how PSS can be beneficial for current product and service design, thus enabling PSS infusion in multiple types of companies.

RESUMO

O avanço tecnológico está a mudar a sociedade de forma rápida. Neste context, a natureza dos produto e serviços também se está a transformar (e.g. produtos inteligentes, a internet das coisas). Os clientes estão mais informados e têm acesso a mais recursos para responder às suas necessidades. Neste contexto, empresas de produtos e serviços, procuram novas abordagens para criar soluções mais completas para seus clientes. Reconhecendo as limitações das ofertas baseadas em produtos físicos, as empresas de manufatura tentam integrar serviços nas suas ofertas e processos de desenho. Do mesmo modo, as empresas de serviços também precisam de mais apoio para melhorar as experiências dos seus clientes enquanto combinam múltiplas evidências físicas de forma coesa. Isto é fundamental para possibilitar experiências positivas.

Existem formas diferentes para conceptualizar serviço e criar novas soluções. Por um lado, a abordagem de sistemas de produtos e serviços (PSS) integra componentes de produto e serviço, bem como as componentes de redes organizacionais para criar ofertas integradas. Por outro lado, a abordagem de Design de Serviço examina e integra a perspetiva holistica da experiência do cliente e cria formas inovadoras para apoiar os processos de co-criação de valor entre stakeholders. Embora complementares, as abordagens de PSS e Design de Serviço ainda não foram integradas. As complementaridades destas abordagens pode melhor apoiar as empresas a criar novas soluções de sistemas de produtos e serviços, desenvolver seus processos de design, e melhorar o posicionamento comercial e de negócio das empresas.

Esta tese investiga como é que abordagens de PSS e o Design de Serviço podem ser combinados para melhor apoiar o design de soluções integradas de sistemas de produtos-serviços que melhorem os processos de co-criação de valor, em vários contextos de design. Para responder a estes desafios, os objetivos da tese são: (1) Explorar lacunas e complementaridades das abordagens de PSS e Design de Serviço para criar uma framework conceptual; (2) Desenvolver uma nova abordagem PSS e respectivos modelos de design para designar soluções integradas de sistemas de produto e serviço, a partir de uma perspectiva integrada, desde as atividades de exploração até o

desenvolvimento de maquetes e protótipos; (3) Compreender como é que a abordagem PSS pode ser integrada com as abordagens de Design de Produto e com Design de Serviço para as enriquecer.

Seguindo uma abordagem de Design Research, os objetivos da tese resultaram em três trabalhos de pesquisa e três contribuições. O estudo (1) analisa lacunas e complementaridades das abordagens de PSS e Design de Serviço através da S-D Logic, com base na revisão da literatura. O desenvolvimento conceptual levou à criação de uma linguagem mais unificadora, e uma framework que descreve potenciais sinergias entre as disciplinas de PSS, Design de Serviço e S-D Logic, que não estavam previamente integradas. O estudo (2) introduz uma nova abordagem integrada de PSS e modelos. A abordagem integra a perspectiva co-criativa e human-centered do Design de Serviço com a perspectiva organizacional do PSS, ao longo das diferentes etapas do processo de design. A abordagem é validada através de um estudo de caso numa empresa que desenha equipamentos de laboratório. A aplicação permitiu desenvolver um conjunto de novas soluções integradas que resultaram em protótipos parcialmente implementados. O estudo (3) avança as contribuições anteriores e explora como é que a abordagem PSS pode enriquecer as abordagens de Design de Produto e Design de Serviço, que são importantes nas empresas de manufactura e de serviço. Um estudo de caso múltiplo com 10 projetos que adotam Design de Produto e Design de Serviço respectivamente, foi efetuado para explorar as questões.

A tese contribui para evoluir a área de pesquisa de design de PSS, integrando as perspectiva de PSS com design de serviço, que ainda não estavam integradas. Assim, contribui também com um novo método que melhor apoia o desenho de novas soluções integradas de sistemas de produtos e serviços; e permite compreender como é que PSS pode ser benéfico para enriquecer abordagens de design de produto e design de serviço, contribuindo para uma maior infusão de PSS em diversas empresas.

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1. INTRODUCTION

Globalization and technology evolution have led to rapid socio-technical changes in economies (Ostrom, Parasuraman, Bowen, Patrício, & Voss, 2015). Moreover, the dynamics and saturation of modern markets (Normann, 2001), as well as the rapid mutation of customer needs and behaviors call for new strategies and approaches to co-create value in innovative ways (Lush & Vargo, 2014; Michel, Brown, & Gallan, 2008). In this competitive and evolving landscape, service can sometimes represent the most added value (Ostrom et al., 2015; Teixeira, 2015). Service is significantly reshaping the way companies innovate their offerings and businesses, with a focus on how they can co-create value with their customers. From a Service-Dominant logic, value cannot be pre-produced or embedded in products (Vargo & Lusch, 2008, 2016). Value is rather co-created by customers and product/service providers that are connected through different value propositions, i.e. their offerings (Chandler & Lusch, 2015). This can open new opportunities for product/service innovation.

Today, manufacturing companies increasingly infuse service in their product offerings to improve their value propositions, in a servitization process (Oliva & Kallenberg, 2003). Servitization can be characterized as a transformational journey, where manufacturers seek to develop innovative capabilities (Raddats, Baines, Burton, Story, & Zolkiewski, 2016) and organizational processes to create revenue from service (Baines, Bigdeli, & Bustinza, 2017). The application of such process usually results in product-service system solutions (Baines, Lightfoot, Benedettini, & Kay, 2009; Kowalkowski, Gebauer, Kamp, & Parry, 2017; Oliva & Kallenberg, 2003; Tan, Matzen, McAloone, & Evans, 2010). At the same time, service companies also pay additional attention to physical evidences. Physical evidences are the tangible attributes of a service, or design objects in the service environment, and are key to enable smooth customer experience (Berry L., Wall, & Carbone, 2006; Lo, 2011; Yoon, Pohlmeyer, & Desmet, 2016). In this context, companies increasingly attempt to enhance customer experiences by differentiate their offerings (Zomerdijk & Voss, 2010). However, this requires holistic and integrated perspectives of the multiple levels of problems.

The integration of both physical product and service components into more integrated value propositions is an important concern that is considerably evolving in multiple contexts, for both manufacturing and service companies (Baines et al., 2017; Morelli & Tollestrup, 2009; Raddats et al., 2016). To address this issue, new approaches were developed in the last decade, in particular Product-Service Systems (PSS) and Service Design.

Product-Service Systems (PSS) have gained increased attention in both academia and industry, in particular for researchers engaged with sustainability, business and design-related areas (Tukker, 2015). Product-service systems solutions can be defined as a mix of product and service components, designed and combined so that they are jointly capable of fulfilling customer needs and deliver value-in-use (T. S. Baines et al., 2007; O. Mont & Tukker, 2006; Tukker, 2015). Traditional views of PSS usually focused on performance, and emphasized ownerless solutions. In this perspective, manufacturers remain in ownership of the product component of the overall solution, providing access to specific products and customized services to customers (Tukker, 2004). This represents a shift to a more functional economy, focused on resource efficiency as opposed to consumption (Raddats et al., 2016). However, given the increasing competitive and socio-economical pressure, product-service systems are increasingly becoming the offering with which companies distinguish themselves from competitors (Rymaszewska, Helo, & Gunasekaran, 2017), but the questions of where, how and what directions to take need further research.

Designing product-service system solutions requires integrating product and service and create additional value (Vasantha, Roy, & Corney, 2015). The first PSS design approaches developed methods focused on improving the use stage of the product, enhancing technical efficiency and performance while reducing the amount of waste produced in production and consumption processes (Aurich, Fuchs, & Wagenknecht, 2006; Aurich, Mannweiler, & Schweitzer, 2010; Cavalieri, Pezzotta, & Shimomura, 2012). Although these approaches are important to improve technical systems, they tend to interpret products and services as separate objects of design. Additionally, the social components of PSS tend to be overlooked (Morelli, 2002b; Rexfelt & af Ornäs, 2009), focusing on the economical or environmental gains of these solutions.

More recent PSS approaches developed new methods that emphasize the emotion and customer experiences to improve acceptance and diffusion (Ceschin, Vezzoli, & Zingale, 2010; Stacey & Tether, 2014), which have been identified as important PSS research challenges (Baines et al., 2017; Tukker, 2015). The design perspective of PSS focuses on the social component of integrated solutions, investigating customer behavior regarding new products, services and technology (Morelli, 2002a; Morelli & Tollestrup, 2009). However, more recent perspectives of value co-creation and service still remain weakly integrated in the PSS design process. This thesis addresses this challenge, by complementing PSS organizational view with a Service Design approach, which has gained attention in Service Research.

In parallel to PSS, the design discipline is also transforming and progressively moving from designing objects (i.e. industrial design), to service, experiences and change (Norman, 2010; Yee, Jefferies, & Tan, 2014). Service Design is seen as both a new field of design (Kimbell, 2011) and a discipline that emerged at the intersection of multidisciplinary service fields (Patrício & Fisk, 2013).

Service design is a holistic, human-centered and co-creative approach to envision and create new service (Mager, 2009; Meroni & Sangiorgi, 2011; Wetter-Edman, Sangiorgi, Holmlid, Grönroos, & Mattelmäki, 2014). It has evolved from being considered as a specific stage of the new service development process (Yu & Sangiorgi, 2014) to a broader approach that includes the understanding of customer experience (Teixeira et al., 2012) and the design of service at multiple levels (Patrício, Fisk, e Cunha, & Constantine, 2011; Teixeira et al., 2017). However the expansion of Service Design to later stages of the development process still needs improvement, to facilitate implementation of service solutions (Lin, Hughes, & Katica, 2011; Yu & Sangiorgi, 2014, 2017). This thesis addresses this call by bridging Service Design human-centered and co-creative perspective with the organizational- and network-oriented view of PSS to create a new integrated PSS approach and support the design of more integrated solutions for value co-creation.

Designing more integrated good-service solutions is identified as a priority in both Service research and PSS research (Baines et al., 2017; Ostrom et al., 2015). This topic is also relevant for industries as they need more support to co-create integrated solutions

(Baines et al., 2017; Baines, Lightfoot, Benedettini, et al., 2009). On the one hand, manufacturers infuse service in their offerings but acknowledge the need to better understand customer experience (Baines, Lightfoot, Benedettini, et al., 2009; Rexfelt & af Ornäs, 2009). On the other hand service companies increasingly deal with multiple service evidences that need to be integrated in service solutions. The physical evidence in service is paramount to deliver smooth customer experiences (Berry L. et al., 2006; Lo, 2011; Zomerdijk & Voss, 2010).

In this context, PSS and Service Design have complementary perspectives that can support the design of more integrated good-service solutions for value co-creation, but these approaches have not yet been integrated. It is the aim of this thesis to bridge them by (1) analyzing their overlaps and complementarities and create a more unified PSS design framework (2) develop a new integrative PSS approach and respective design models to support the co-creation of integrated product-service system solutions and (3) to understand how PSS can be integrated and enrich Product Design and Service Design approaches, which remain important backbones of current manufacturing and service companies.

2. CONCEPTUAL BACKGROUND

The previous section highlighted the challenges faced by organizations in designing integrated product-service system solutions. It also introduced the key concepts, such PSS design, Service Design and service. PSS and Service Design are two important and expanding research fields that support the design of more integrated product-service system solutions. The following section presents a brief review of the literature, as well as the challenges, the main research gaps and research questions addressed in this thesis.

2.1. Product-Service System (PSS)

Product-Service System (PSS) can be defined as an approach that combines product and service components that together provide value-in-use for customers (Baines et al., 2007). Evolving to PSS requires innovative strategies (Ceschin & Gaziulusoy, 2016), which include collaborative organizational-networks of stakeholders that co-create value with customers for a determined period of time (Tukker, 2015).

Within PSS research, product-service system solutions may fall within three categories: product-, use- and result-oriented (Tukker, 2004). Product-oriented solutions are product-based solutions with a traditional view of services. Services in this perspective are complementary to physical products e.g. maintenance and repair. The two latter categories of solutions (use-and result oriented solutions) increase the opportunities to innovate value propositions through service. Use-oriented PSS solutions usually make the physical products available for use to customers leading to more optimized consumption patterns (i.e. leasing or sharing services). This type of PSS also brings economic incentives for the manufacturer to expand the life-span of physical products as the use of additional resources (e.g. new materials) can lead to higher operations costs. The result-oriented PSS solutions, on the other hand, do not focus on specific products or services, but rather on performance (e.g. selling washed clothes as opposed to selling washing machines). Result-oriented solutions can have an important impact on co-creation processes among customer and product/service providers (Baines et al., 2017; Baines, Lightfoot, Benedettini, et al., 2009; Tukker, 2015). Examples of companies delivering these solutions are Xerox and Rolls-Royce (Kowalkowski et al., 2017). Xerox shifted its business from selling printers to selling copier management

service systems, whereas Rolls-Royce changed from selling engines, to selling power-by the hour long-term contracts (Davies, Brady, & Hobday, 2006). In both cases, the manufacturers remain in ownership of the product component, and profit from the service delivered. The manufacturer thus can create additional revenue and profit from service, improve its response to customer needs, and set higher barriers to competition (Baines et al., 2017; Oliva & Kallenberg, 2003).

In traditional application of PSS approaches, customers are relieved from certain tasks and/or activities as providers retain most of the activities related with maintenance and repair of product components of the solution. This perspective of PSS emphasizes organizational-oriented networks as the key co-creators of value. The customer is part of the network, but has a minor role. This perspective of PSS has been fairly developed in PSS literature and traditional PSS design approaches, focusing on improving the efficiency and performance of technical systems (Cavalieri & Pezzotta, 2012; Vasantha, Roy, Lelah, & Brissaud, 2012).

However, the implementation and diffusion rate of these solutions still remains rather slow (Baines et al., 2017; Tukker, 2015). Studies identify internal and external barriers as potential causes (Tukker, 2015; Vezzoli, Ceschin, Diehl, & Kohtala, 2015). Internal barriers refer to the need to embed PSS culture in organizations, emphasizing the issue on enabling change in organizational processes. External barriers are related with the cultural shift in customer practices and behaviors, and acceptance of ownerless solutions (Rexfelt & af Ornäs, 2009; Vezzoli, Kohtala, Srinivasan, Xin, & Fusakul, 2014; Vezzoli et al., 2015). Manufacturers acknowledge that it is increasingly important to understand value-in-use from the customer perspective and not only focus on the offering per se (Baines, Lightfoot, Benedettini, et al., 2009).

2.2. PSS design

Designing integrated good-service solutions, combined with a broader understanding of social aspects of PSS (i.e. customer acceptance, understanding of customer behaviors), have been identified as PSS research priorities (Baines et al., 2017; Roy, Shehab, & Tiwari, 2009). The growing importance of PSS is reflected in the volume of contributions in different research domains (Beuren, Gomes Ferreira, & Cauchick Miguel, 2013).

The evolutionary path for PSS design started from a sequential stage-gate based engineering to concurrent engineering such as systems process modeling techniques, CAD supporting tools and frameworks for knowledge reuse, and representation techniques for functions, activities and product behaviors (Cavalieri & Pezzotta, 2012). These approaches, which represent a more traditional perspective of PSS design, emphasize the effective use of resources within organizational-based networks (Aurich et al., 2006; Hara, Arai, Shimomura, & Sakao, 2009; Maxwell, Sheate, & van der Vorst, 2006; Vasantha et al., 2015, 2012). These methods and techniques are useful to understand functions and supporting processes, as well as to improve the efficiency and performance of technical systems. However, they have little capacity to understand and incorporate social components within PSS (Morelli, 2002a).

Additionally, the service components are generally under-defined when compared to traditional product engineering within PSS (Cavalieri & Pezzotta, 2012). This can originate incongruence of product-service system solutions through the customer's eyes (Valencia Cardona, Mugge, Schoormans, & Schifferstein, 2014), leading to risks of creating negative customer experiences (Carreira, Patrício, Jorge, & Magee, 2013).

To address this issue, a Design perspective of PSS has been developed to expand its scope from technical-based to socio-technical systems (Morelli, 2002a, 2006b; Morelli & Tollestrup, 2009). Design is a user-centered discipline that has been evolving in the last decades, from the design of objects to the design of experiences (Yee et al., 2014). Within PSS research, Morelli et al. have adopted a design perspective to investigate customer behaviors with respect to new products, technologies and services, and includes the analysis of service network components (Morelli, 2006a; Morelli & Tollestrup, 2009). The techniques developed emphasize the motivation of stakeholders within collaborative networks, and support resource coordination and combination. Additionally, Carreira et al. (2013) have developed a new method to incorporate customer experience requirements into the design of PSS (Carreira et al., 2013). This design perspective thus bridges the traditional engineering perspective of PSS, based on efficiency, to the social and experience components of design. However, more recent perspectives of value co-creation and service still remain weakly integrated in the PSS design process. Further incorporation of a service perspective is needed. The next

chapter explains how service has evolved within Service Research, and outlined the main research challenges in service design.

2.3. Service and Service-Dominant logic (S-D Logic)

The earliest perspective interpreted services through the same blueprint of product marketing (Shostack, 1977). In this context, they were defined "as different from products" (Edvardsson, Gustafsson, & Roos, 2005; Lovelock & Gummesson, 2004) or characterized as add-on to products to facilitate product sales. The IHIP model materializes this perspective to some extent. IHIP stands for intangibility (services are not tangible) heterogeneity (it is not possible to reproduce a service as the people involved are unique), inseparability (services are consumed and produced at the same time) and perishability (services cannot be stored or saved) (Zeihaml, Parasuraman, & Berry, 1985). This model characterizes some factors when dealing with the design of service (e.g. time, interactions, and ownership) and is still useful today. However the rapid development of information and communication technology led to some revision of this IHIP framework (Edvardsson et al., 2005; Shostack, 1977). For example, the inseparability of production and consumption or perishability can be overcome by technology through web-based distance learning, or long-distance surgery performance (Moeller, 2010). As Edvardsson et al. (2005) mention, "we should not generalize the characteristics of services but (…) understand the conditions under which they apply" (Edvardsson et al., 2005).

As a consequence, service was expanded into a new and broader perspective – Service-Dominant Logic (S-D Logic) (Vargo & Lusch, 2008, 2016) - that can be applied to all value co-creating processes, whether they involve products, services (in the traditional sense), or a combination of both (Ostrom et al., 2015). Within S-D Logic, service can be defined as the application of competences for the benefit of another entity (Lush & Vargo, 2014). Value is co-created between product/service providers and customers, and is determined by the beneficiary of the solution (Vargo & Lusch, 2008, 2016). This implies that value cannot be pre-produced nor be embedded in products (producer sphere), but rather emerges in-context and while-in-use (Edvardsson, Tronvoll, & Gruber, 2011), within the customer sphere (Grönroos, 2008, 2011).

S-D Logic changes the way organizations create and manage their offerings, as they need to become more focused on supporting the value co-creation processes with their customers and customer networks (Morelli & Götzen, 2017). From the companies' point-of-view this implies that product and service interfaces and process can still be designed by the product/service provider. However the exact outcome of the interaction cannot be fully controlled (Meroni & Sangiorgi, 2011; Morelli & Götzen, 2016) because the arena where value co-creation processes occur changed from producer value chain, to constellations of actors including customers. As such service should be designed for value co-creation.

S-D Logic also opens up new opportunities for innovation by enabling new forms of value co-creation with customers. S-D Logic and PSS share similar perspectives on value-in-use and solutions co-creation. This alignment between S-D Logic and PSS is important to support service and PSS infusion in organizations.

2.4. Service Design

Service design has gained increase attention in service research (Ostrom et al., 2015), as it brings new ideas to life and can support manufacturing and service companies to create new value propositions. Service Design is characterized as an holistic, human-centered and co-creative approach to envision new service (Mager, 2009; Meroni & Sangiorgi, 2011; Wetter-Edman et al., 2014). S-D Logic is a key pillar of Service Design as it provides a framework to understand service systems in action (Wetter-Edman et al., 2014) and brings forwards a modern view of value co-creation. Customers co-create value when they use and integrate these product/service providers' solutions with their own constellation of resources (van Riel et al., 2013). The fast pace of technological development is considerably changing how customers and product/service providers interact and co-create value (Ostrom et al., 2015). Within this context, it is important to consider the multiple ways through which customers and product/service providers may interact, and analyze the overall system of resources available to the customer.

To address this challenge, Service Design has evolved from a restrict stage in the new service development process, which defines prerequisites for service concept, service system and service process (Yu & Sangiorgi, 2014), to a broader and more holistic

approach which includes understanding customer experiences and creating new service concepts, systems and encounters (Patrício et al., 2011). More recent work integrated contributions from management and interaction design to support the creation of technology-enabled services and enhanced current Service Design models (Teixeira et al., 2017). Although the models address back-stage processes, their emphasis remain on front-stage activities and provide little insights on the physical evidence and product components required to support the service experience.

Another challenge also outlined as a research priority concerns the need to support service infusion in companies (Ostrom et al., 2015). With the exception of some studies in public (Lin et al., 2011) and private organizations (Zomerdijk & Voss, 2010), few empirical studies exist on how Service Design can support companies in their path towards service infusion. Moreover, these studies mainly focus on the role Service Design in the early stages of the design process, while later stages remain unaddressed (Yu & Sangiorgi, 2017).

Service Design needs to be better incorporated in later stages of the development process, so design contributions can be more effectively incorporated in the implementation process. Moreover, service design also needs to be better infused into current companies' design practices, to better support their transition towards service (Bailey, 2012; Sabine Junginger, 2014; S Junginger & Sangiorgi, 2009).

2.5. Research Gaps

The analysis of previous literature on the design of PSS solutions shows there are important research gaps PSS and Service Design. Literature outlines two main issues in PSS research, namely customer acceptance of integrated product-service system solutions and the infusion of PSS design in organizations. On the other hand, Service Design needs to be better intertwined with organizational processes to improve the implementation and impact of service in companies. These research gaps are further elaborated below.

Within PSS, value needs to be better understood from the customer perspective (Baines, Lightfoot, Benedettini, et al., 2009). Previous research from Carreira et al., (2013); Morelli, (2006a); Morelli & Tollestrup, (2009) constitute important advances in PSS

design, but customer experience and more recent S-D Logic perspective of value co-creation should be further integrated into the PSS design to foster customer acceptance (Valencia, Mugge, Schoorman, & Schifferstein, 2015; Valencia Cardona et al., 2014). Design methods and tools should be developed taking into account the collaborative effort required to design an integrated solution, which has implications for all parties involved: from the determination of the experience (Rexfelt & af Ornäs, 2009) and benefits co-created, to the definition of the supporting backstage product-service system and organizational networks (Morelli & Tollestrup, 2009).

Second, there is still a high perceived risk for companies that want to make the transition towards PSS as it can require important organizational changes (Rymaszewska et al., 2017). More than a full-transition, some authors argue that partial PSS infusion, instead of making a full transition towards PSS can be more beneficial for some companies (Kowalkowski et al., 2017). However, there are still few design insights into how to support the partial expansion towards PSS. Designing integrated solutions with both product and service components still needs further research (Valencia et al., 2015).

Additionally, designing from an integrated perspective is also important for service organizations. Service companies increasingly understand the importance of physical evidence and product components of their service offering (Lo, 2011). However, research on the impact of PSS approaches in these contexts is still widely under-explored (Baines et al., 2017).

Service Design has been evolving towards more holistic perspectives to co-create new service solutions, incorporating the customer experience in the design of multi-channel touchpoints across the service journey (Bitner, Ostrom, & Morgan, 2008; Patrício et al., 2011). However, current Service Design methods and tools still focus on the earlier stages of the design process, especially concept generation and prototyping. As such, they need to be further integrated with organizational processes, so they can be better incorporated in later implementation stages (Junginger & Sangiorgi, 2009; Lin et al., 2011; Sangiorgi & Prendiville, 2014). Analyzing and co-creating new customer experiences is important, but overlooking the organizational processes and networks

required to make those experiences come true can jeopardize the implementation and impact of service (Sangiorgi & Prendiville, 2014).

Second, Service Design methods and tools have evolved towards more holistic approaches, encompassing experiences, physical evidences, actors and processes (Bitner et al., 2008; Patrício et al., 2011; Teixeira et al., 2012; Teixeira et al., 2017; Wetter-Edman et al., 2014). However, greater emphasis is needed when it comes to understand the specific characteristics of physical products, which are often overlooked within service solutions (Berry L. et al., 2006; Lo, 2011). Physical evidences are important and their nature is changing because of the technology (Rymaszewska et al., 2017). As such additional research is needed to address this issue.

2.6. Research questions and objectives

The overall aim of this thesis is to support the design of integrated product-service system solutions for value co-creation. PSS and Service Design have important differences, but are also highly complementary. PSS has evolved from an organizational-network perspective to develop new product-service system solutions. On the other hand, Service Design is more human-centered and co-creative approach to create new service. Literature indicates a movement in PSS research, evolving towards the S-D logic paradigm, but this trend is still at its infancy (Baines et al., 2017). Given the design challenges and research gaps presented above, we outline three main research objectives: (1) Explore overlaps and complementarities between PSS and Service Design to develop an integrated PSS conceptual framework and build a research ground at the intersection of these two areas; (2) Bring together PSS design and Service Design to develop an integrative PSS design approach that can support manufacturing industries to design integrated value propositions; and (3) Understand how can PSS design be partially incorporated to enrich Product Design and Service Design approaches for a smooth transition towards PSS solutions.

Objective 1: Explore overlaps and complementarities between PSS and Service Design to develop a conceptual framework

PSS and Service Design have complementary perspectives to design new solutions, but these approaches are not very well integrated. The thesis explores the overlaps and

complementarities between PSS and Service Design, based on literature review, and create a unifying conceptual framework through the lens of S-D logic. S-D logic has emerged as a new perspective on value co-creation (Vargo & Lusch, 2008, 2016). This logic advocates that value cannot be pre-produced, but is rather co-created when customers interact with product/service providers. This has important implications for companies. The notion of value co-creation, resource integration and service systems that are part of the S-D logic (Vargo & Lusch, 2008, 2016) have inspired similarities with Service Design (Wetter-Edman et al., 2014), but these have not yet been incorporated in PSS.

The conceptual framework was built to create the foundation and support future research at the intersection of PSS and Service Design, outlining their complementary views on value co-creation, as well as to bridging the systemic and organizational-network oriented view of PSS with the human-centered and holistic approach of Service Design.

Objective 2: Develop a new integrative PSS approach and design models to support the design of product-service system solutions

Second, this thesis aims to develop an end-to-end integrative PSS design approach and a set of models, to support the understanding of customer experience within PSS context, and design integrated product-service system solutions for value co-creation.

Many PSS methods lack a systematic and coherent design process (Vasantha et al., 2012), and often do not consider customer experience (Stacey & Tether, 2014). The new integrative PSS approach and design models were developed to address this issue and support manufacturing industries to design new product-service system solutions from a more integrated perspective: looking both at the organizational-networks components from PSS, as well as the human-centered and co-creative perspective of Service Design, throughout the different stages of the design thinking process.

The integrative PSS design approach aimed also to support companies to shift to a PSS-oriented mind-set, which as be pointed out as a very significant PSS research direction (T Baines et al., 2017; Raddats et al., 2016).

Objective 3: Understand how PSS can be incorporated with Product Design and Service Design to enrich these approaches

Third, the present thesis aims to understand how a PSS approach can enrich the design process and design outcomes of Product Design and Service Design. Product Design and Service Design are important design approaches to create new solutions. Product Design has an extensive background to support the development of new material artifacts (Kim & Lee, 2016; Ulrich, Eppinger, & Goyal, 2011).Also, Service Design approach has emphasized the value co-creative processes among stakeholders and created new methods and tools to envision service solutions (Patrício et al., 2011; J. Teixeira et al., 2012; Yu & Sangiorgi, 2017).

Manufacturing and service companies adopt different design practices when it comes to designing new solutions. Product Design in particular has been a substantial backbone of manufacturing industries. Although the PSS transition is advised (Rymaszewska et al., 2017; Valencia et al., 2015), recent studies indicate that a partial expansion towards PSS can be preferred rather than full-transition (Baines et al., 2017; Kowalkowski et al., 2017). As such, it is important to understand how some components of PSS can be incorporated in product design and service design to support this partial transition.

Current design approaches and practices need to be better understood (Junginger, 2014). A vast majority of PSS contributions focuses on supporting the transformation from goods to service-oriented businesses and limited research explore strategies for service companies to expand towards PSS (T Baines et al., 2017; Kowalkowski et al., 2017; Raddats et al., 2016), without losing the product design focus.

Rather than a full transition, certain cases and companies can benefit from partial PSS infusion in their design process. To explore this issue and answer to Baines et al.'s call of exploring alternative strategies to enrich PSS research (Baines et al., 2017), the third objective is to understand how Product Design and Service Design teams can infuse PSS components in the design process, to improve their process and solutions, without making a full transition to PSS, therefore maintaining the focus of product design and service design. This knowledge can better guides companies using Product Design or

Service Design approach and practices, to co-create more integrated solutions through either full or partial use of PSS approach.

3. METHODOLOGY

To address the three objectives previously presented, the thesis uses Design Research as an overall research approach. Design Research is concerned with studying the artificial phenomena of design (Buchanan, 2001) and aims to advance the understanding of design and designing (Blessing & Chakrabarti, 2009; Fallman, 2008; Ken Friedman, 2008). Design Research also encompasses the development of new artifacts to support designing activities (Fallman, 2008). Given that the present thesis focuses on creating new design artifacts as well as improving design activities concerning the co-creation of integrated solutions, Design Research was adequate.

To create new artifacts (objective 1 and objective 2), design research comprises two main activities: (1) building and reflecting upon new artifacts to address a relevant class of problems and (2) evaluating the artifacts in use in terms of efficiency and effectiveness to the problems identified (Forlizzi, Zimmerman, & Evenson, 2008; Manzini, 2008; Zimmerman & Forlizzi, 2008). The current thesis aims to better support the design of new integrated product-service system solutions (problem), through the development of a framework and approach that bridge PSS and Service Design, which has been identified as a research priority in PSS research.

To study designerly ways-of-knowing when it comes to co-creating new integrated solutions (objective 3), design research can use social science methods. These encompass more traditional academic procedure of qualitative research - sample design, data collection and analysis – and develop more analytical work, adopting a more distant role regarding the object of study (Fallman, 2008).Following Design Research guidelines, the research followed three main following stages:

Study 1: To develop an integrated PSS conceptual framework, building upon the overlaps and complementarities between PSS, Service Design and S-D Logic, an analytical conceptual research was used (Meredith, 1993). Literature review on PSS, Service Design and S-D logic were analyzed and synthesized into a conceptual framework that provides a theoretical foundation for the development of a new integrative PSS approach (study 2).

Study 2: To develop an end-to-end approach combining PSS and Service Design approaches to support the design of integrated product-service system solutions, we followed a Design Research approach (Fallman, 2008; Forlizzi et al., 2008) and complement it with Design Science Research (Hevner, March, Park, & Ram, 2004). Following this methodological approach, the research process followed three stages: (stage 1) Conceptual development of the integrative PSS approach, (stage 2) Application of the integrative PSS approach, following the design thinking stages (Johansson-Sköldberg, Woodilla, & Çetinkaya, 2013) and (stage 3) Evaluation stage, encompassing Design Science Research guidelines. The application stage was undertaken in a manufacturing industry to design new smart-lab solutions. Multiple research activities were undertaken during the period of six months with participants including design team (6 participants), stakeholders of the project (10 participants), and customers (over 23 participants in co-creative sessions and laboratory visits).

Study 3: To understand how PSS approach can enrich Product Design and Service Design, a multiple case study approach was followed (Yin, 2003; Zomerdijk & Voss, 2010). The study was undertaken with 5 projects using a Product Design approach, and 5 design projects using a Service Design approach. The study used a qualitative research approach (Charmaz, 2014; Neuman, 2014; Strauss & Corbin, 2015) and followed ethnographic guidelines during the period of 8 months to develop an in-depth understanding of the multiple design activities developed by each team. Moreover, the PSS approach was infused in each design environment to understand the changes occurring throughout the design process. The study starts by explaining case selection, data collection and data analysis procedures following the guidelines of (Voss, Tsikriktsis, & Frohlich, 2002; Yin, 2003, 2014). Data analysis included triangulation of the multiple evidences gathered during the field study (Yin, 2003), and progressive data codification, uncovering the most important categories inductively (Charmaz, 2014; Strauss & Corbin, 2015). Additionally the multiple evidences collected were triangulated to increase the validation of the findings (Yin, 2003). The study first compares product design and service design approaches, theoretically and empirically, and proceeds by explaining how PSS enriched these approaches throughout the design process.

The following section explains Design Research approach used throughout the study. It also explains the research process and multiple methods used to address the objectives mentioned in the introduction.

3.1. Design and Design Research

Design is a discipline concerned with solving ill-defined, real-world problems (Buchanan, 1992; Rittel & Webber, 1973). The areas where Design takes place can be categorized from symbolic and visual communication, to design of material objects, design of activities and service, as well as design of complex systems or environments for living, working playing and learning (Buchanan, 1992). The transition of Design as a practice-based discipline to research highlighted the issues concerning the creation of design knowledge, and the difference between scholarly research and creative practice (Melles & Feast, 2010).

Three fundamental epistemological positions are debated within Design Research, namely direct making (related to subjectivism), reflective practice (related to constructivism) and rational problem-solving (related to objectivism) (Melles & Feast, 2010). Direct making, that is, research where the end product is a solution, has been criticized since the connection between data collection, analysis and results are often not always clear, creating knowledge that is difficult to verify (Collins, Joseph, & Bielaczyc, 2004; Friedman, 2003). Within the positivist stance, Design as the science of the artificial considers design research as a systematic inquiry into the nature of design activity (Simon, 1969). Later, design research was aligned with constructivism which argues that designing needs to be complemented with reflecting upon the process of making (Cross, 2001; Dorst, 2008; Schön, 1983).

The debate about the importance of rigor in design research has become a major topic that is still relevant (Davis, 2008). The concerns of Collins et al. (2004) and Friedman (2003) are addressed by incorporating additional research perspectives such as the Design Science Research to improve the research rigor within the constructivist view of design research, especially in later stages to validate the research findings. The activities of making and reflective practice are embedded throughout the research process to support the development of new insights that contribute to design research and practice.

The research is also supported by following qualitative research guidelines in specific stages of the research.

3.2. Research design

This thesis deals with the challenge of supporting the design of more integrated product-service system solutions for value co-creation. As such, it follows an overall Design research approach which focuses on studying the artificial phenomena of design (Buchanan, 2001) and aims to advance the understanding of design and designing (Blessing & Chakrabarti, 2009; Fallman, 2008; Ken Friedman, 2008). Design research has evolved considerably over the years, and was adapted according to the context. Given the objectives outlined, the thesis follows multiple research activities, and combines different perspectives within design research namely, design research to build and reflecting upon new artifacts (Fallman, 2008; Forlizzi et al., 2008; Forlizzi, Zimmerman, Forlizzi, Stolterman, & Zimmerman, 2009), and design research as an approach to understand and study design i.e. design studies (Fallman, 2008). Study 1 is conducted through a literature review and conceptual development of a framework focused on the theory of design and value co-creation. Study 2 is aligned with the design research outlined by Fallman (2008) as it focuses on the development of new artefact (integrative PSS method, and models) to support the development of new product-service system solutions. Finally, study 3 is more aligned with design studies as it uses more scientific-based methods (e.g. observations) to study activities related with design and designing.

The research process included multiple stages that are outlined in the Table 1 and Figure 1. Topics, methods, data collected and the context of each study are outlined. The next section explains the research process and methods used for each stage.

Study 1: literature review to develop an conceptual framework for integrating PSS and service design

To address the first research question of the thesis, conceptual development (Meredith, 1993) and literature review was undertaken to understand the relevant problems and gaps at the intersection of PSS and Service Design. The thesis explores PSS, Service Design and S-D Logic (Costa, Patrício, & Morelli, 2015b, 2016), outlining key

contributions, gaps and complementarities. The synthesis of the literature results in a conceptual framework. The framework outlines the PSS focus on organizational networks, and Service Design focus on human-centered and co-creative processes. The service perspective on value co-creation (S-D Logic) is used explore and bridge the complementarities of these design approaches and create a conceptual framework.

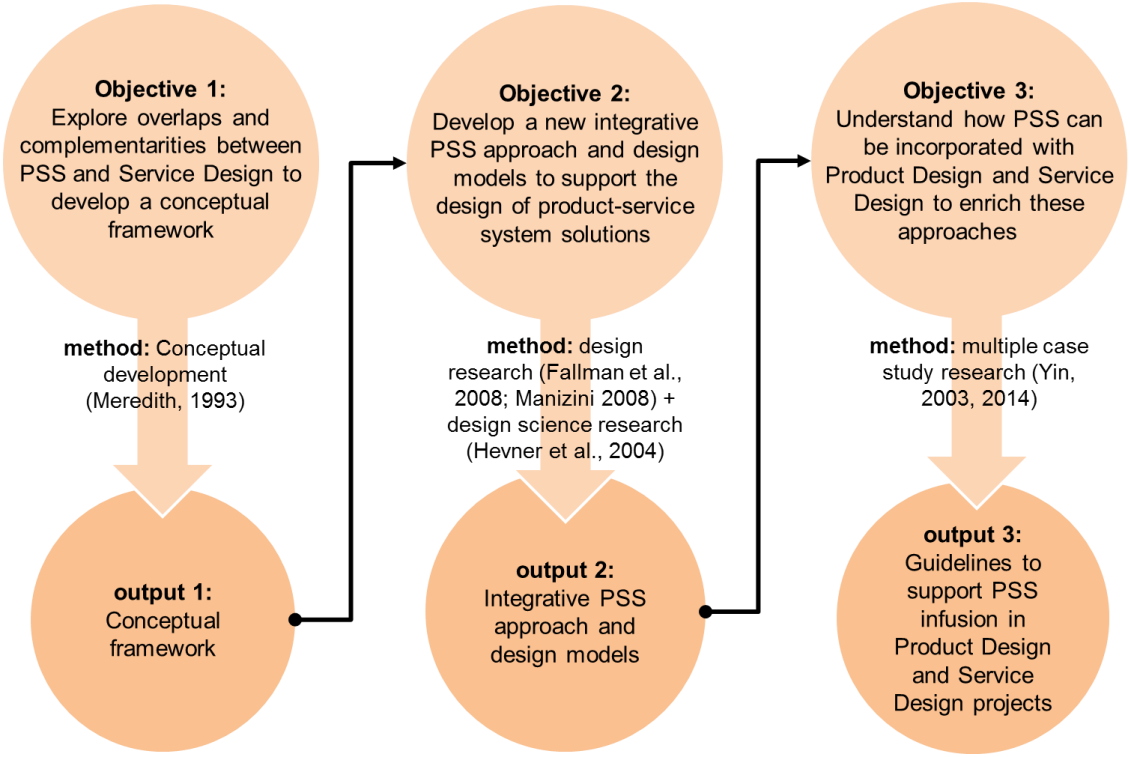

Figure 1. Research design: objectives, research methods and results

Study 2: design research to develop a new integrative PSS design approach, combining PSS and service design, with an application to a smart-lab project

In the area of PSS, design research seeks to develop new design knowledge that can be embedded within configurations of artifacts (Cross, 1999), which are build and reflected upon, in a construction-oriented view (Forlizzi et al., 2008; Zimmerman & Forlizzi, 2008). As such, to address the second objective of the thesis - create a new integrative PSS approach and design models - the study followed a design research approach. According to Manzini (2008), design research comprises two main activities: (1) building new artifacts and (2) evaluating the artifacts while in use (Manzini, 2008). The first activity consists in identifying a class of problem that is relevant and building artifacts that may solve the problems. The second activity consists in reflecting upon the

Table 1. Objective, research methods, data collected and research context

Objectives	(1) Create a unified PSS framework	(2) Create an integrative PSS approach that bridges PSS and Service Design	(3) understand how PSS can be infused and enrich Product Design and Service Design
Method	Conceptual development and literature review	Design Research + Design Science Research & design research criteria	Design Studies + multiple case study research
Field work	-	6 months	4 months + 4 months
Data collection	PSS, Service Design and S-D logic key literature	Creative sessions; laboratory visits, meetings with design director and design team; concept generation workshops, test with customers, internal PSS workshop	Extensive filed study, observations, document review, semi-structured interviews
Context		Laboratory manufacturing industry: smart lab design project	5 Product design projects (MIT-IDM), and 5 Service design projects (FEUP-MESG)

use of these artifacts in context, in terms of efficiency and effectiveness to solve the class of problems previously identified.

The research process follows three stages. Stage (1) involved the conceptual framework of the integrative PSS approach. Stage (2) comprised the application of the integrative PSS approach in a smart-lab project, following the design thinking stages i.e. exploration, creation, prototype and test and implementation (Johansson-Sköldberg et al., 2013). Finally, stage (3) involved the evaluation stage, encompassing Design Science Research guidelines (Hevner et al., 2004) and Design Research criteria (Forlizzi et al., 2008).

Stage 1 starts with the literature review on service design, PSS design and S-D Logic, following guidelines of design research (Manzini, 2008). Literature review supports the development of new artifacts (i.e. integrative PSS method and respective models) in accordance to the analytical conceptual research (Meredith, 1993) and aim to better support the design of integrated solutions in manufacturing companies.

Stage 2 involved the application case follows a design thinking stages of exploration, creation, prototype and test and implementation (Brown, 2008; Johansson-Sköldberg et al., 2013). The application stage follows the conceptual development stage in design research (Manzini, 2008). The exploration stage of the application uses qualitative research in sample design, data collection and data analysis, to develop an in-depth understanding of the customer experience (Charmaz, 2014; Strauss & Corbin, 2015). Following guidelines of qualitative research, the sample was selected according to the relevance of participants to gain in-depth understanding of the different stakeholders' experience. Lab visits, group interviews, observations with field notes and exploratory sessions combined, provided information to develop categories of problems in context. The data analysis was supported through design models, which were evolved iteratively, with the participants of the study. The creation stage used new design models to support the co-creation of new product-service system solutions and new forms of value co-creation between customers and product/service providers. These models were evolved iteratively with the company design team. The prototyping and testing stages were also iterative, going from the construction of new physical products to the storyboards. Finally, the new product-service system solutions co-created were evaluated by the customers of the product-service system solutions.

Stage 3 involved the evaluation stage of the design artifacts developed following guidelines of Design Science Research (Hevner et al., 2004). The present thesis recognizes that reflective practice per se can lack on rigor and robustness (Collins et al., 2004; K Friedman, 2003; Jonas, 2007). As such, the evaluation stage was complemented with design research criteria (Forlizzi et al., 2008) and Design Science Research evaluation stage (Hevner et al., 2004), to evaluate the usefulness and effectiveness of the design artefact developed. The application of the integrative PSS approach and models developed showed that it can support the design of new integrated solutions. Also, following qualitative research guidelines (Charmaz, 2014), the integrative PSS approach was refined and evaluated in an iterative way, through multiple meetings with the design team along the design process and with a final internal workshop.

Design Science Research has been evolving consistently and is spreading across service research (Ostrom et al., 2015; J. Teixeira, 2015). Hevner et al. (2004) claim that built artifacts should be evaluated with respect to the utility provided in solving problems. As such, intervention in the real world is important. The design artifacts were developed together with a manufacturing industry, supporting the development of 5 product-service system solutions, which attests for Design Science Research evaluation criteria. Moreover, data about the effectiveness and utility of the integrative PSS approach was collected through regular meetings with the design team, after data collection and analysis, after the internal the co-creative workshops, as well as in a final internal workshop with the design and development team and CEO of the company. Data collection regarding the integrative PSS approach also followed qualitative research guidelines covering the tenets of sample design, data collection and analysis (Charmaz, 2014; Strauss & Corbin, 2015). The main contributions and limitations of the artifacts were analyzed, and incorporated in the models to refine the approach. Following the same reasoning, the evaluation stage also incorporates Forlizzi et al. (2008) criteria of process, invention, relevance and extensibility (Forlizzi et al., 2008). First (process) the design used was detailed to enable replication and improvement. Second (invention), the integrative PSS approach evolves previous methods of PSS and Service Design by combining their perspectives on customer experience and organizational networks, which were not integrated before. Third (relevance) the application in real-context showed how the method can support the co-creation of integrated solution and support the servitization process. Finally (extensibility), the success of the application indicates that the integrative PSS approach can be applied in other manufacturing settings.

Study 3: multiple case study to examine and compare Product and Service Design approaches, and understand how PSS can enrich these approaches

The third objective of the thesis was undertaken with multiple case study research (Yin, 2003, 2014) to study design practice, with product design and service design projects. Design research goes beyond building new design artifacts, and is concerned with understanding the nature of design itself (Dorst, 2008; Fallman, 2008), designerly ways of knowing (Cross, 2001; Johansson-Sköldberg et al., 2013). This refers to the human-centered, creative and exploratory approach to understand problems, studying how

designers work, think and carry out their activities, use their methods and tools, how the designed artifacts are produced and how well they perform their jobs (Fallman, 2008).

Multiple case study was considered adequate to explore complementarities and gaps of Product Design and Service Design approaches, and to understand how partial PSS infusion can enrich these approaches. Studying multiple cases enhances the robustness of the findings, covers different theoretical and augments external validity (Voss, Tsikriktsis, & Frohlich, 2002; Yin, 2014). Multiple case study is aligned with design studies from Fallman (2008) as both research approaches are concerned with studying a certain phenomenon in context (Fallman, 2008).

Case study research allows the questions *what*, *why* and *how* to be answered when the boundary between context and phenomena is not clear (Yin, 2003, 2014). Within case study research, qualitative research methods were used to select the cases, collect and analyze data from multiple sources following qualitative research guidelines from Charmaz (2014) to enhance research rigor.

First, (case selection) the empirical ground of the research involved 10 design projects. Projects were purposefully selected within two distinct design contexts and according to their relevance to allow heterogeneity and richer qualitative inquiry (Voss et al., 2002): one context included 5 design teams adopting a Product Design approach, whereas the other context included 5 design teams adopting Service Design approach. The introduction of the PSS approach in the two contexts occurred at the initial stages of the design process, more precisely at the end of the exploration stage.

Second, data collection followed the guidelines of qualitative research (Charmaz, 2014; Strauss & Corbin, 2015) and ethnographic research (Murchison, 2010). Qualitative data collection methods included a total of 8 months extensive field study (4 month in each design context), in-situ observations with field notes, document review, collection of artifacts, and semi-structured interviews with the design teams.

The interviews were analyzed, and coded according to the guideline provided by (Charmaz, 2014; Strauss & Corbin, 2015). Data triangulation combined multiple sources of data. This improved the robustness of the results and increased the validity of

the research (Voss et al., 2002; Yin, 2003, 2014). The data processing was partly inductive, which means that the results emerged from the data. As the data collection was undertaken, and interviews were transcribed, new patterns emerged.

The design research methodology outlined in this chapter provides a description of the multiple research activities undertaken throughout the three papers developed. Design research was combined with other research perspectives to improve research rigor. Through this methodology, the thesis can contribute to design research and practice when it comes to support the design new integrated product-service system solutions.

3.3. Thesis outline

This thesis has five parts and is organized around three research papers. The first chapter (introduction) establishes the motivation, explaining the importance of each research area, in particular PSS design and Service Design. Chapter 2 (conceptual background) provides a theoretical foundation, depicting the contributions and research gaps of PSS design and Service Design and objectives of the thesis. The third chapter presents the overall research methodology, explaining how the three projects of the thesis were developed and complement each other to attain the research objectives. Chapter 4 organizes the research papers that are part of the thesis: the first one provides a theoretical basis; the second presents the development of the integrated PSS design approach, with a case study undertaken in a Portuguese laboratory manufacturing industry; the third one explores how PSS approaches can enrich Product Design and Service Design approaches through a multiple case study with 10 design projects. Chapter 5 discusses the contributions of the thesis, taking into consideration the research phases and questions defined. Finally, chapter 6 presents the conclusions, limitations and future research directions.

4. RESEARCH PAPERS

Having introduced the challenges, objectives and methodology of this thesis, the following sections present the three research papers developed. In each paper the challenges and objectives are addressed and the methodology applied. The next paragraphs summarize each research paper.

Paper 1: Revisiting PSS and service design approaches in the light of the S-D logic (Costa et al., 2016)

This paper addresses the first objective of the thesis which is to explore complementarities and differences of PSS and Service Design, as well as creating a conceptual framework. Through literature review, the paper analyses PSS and Service Design, and positions their characteristics following the fundamental concepts of the SD-Logic: value, co-creation, resource integration and actors, and service systems' roles. The conceptual framework developed explores the complementarities of the design approaches, and attempts to bridge them. The paper builds upon earlier contributions that were presented and published in product- and service-oriented conferences (Costa, Patrício, & Morelli, 2015a; Costa et al., 2015b).

Paper 2: Bringing service design to manufacturing industries: integrating PSS and service design approaches (Costa, Patrício, Morelli, & Magee, 2017)

The second paper presents a new integrated PSS approach and respective models, and concerns the second objective of the thesis: integrating PSS and Service Design. The paper follows a Design Research approach and complements it with the evaluation stage of Design Science Research (Hevner et al., 2004) and design research criteria (Forlizzi et al., 2008). It conceptualizes PSS and Service Design perspectives, develops and applies a set of new PSS design models that combine contributions these approaches throughout the different stages of the design process. The application case was undertaken in a manufacturing industry during the period of six months, and has resulted in five different product-service systems solutions which were validated with customers. The evaluation stage of the new integrative PSS method was undertaken throughout the design process and on regular meetings with the team. Similarly to the

previous paper, the new integrated PSS approach results from discussions of published and presented work in journal and conferences (Costa et al., 2015a, 2015b, 2016).

Paper 3: Expanding the boundaries of Product Design and Service Design approaches through PSS design (Costa, Patrício, Morelli, & Cressy, 2017)

Finally, the third research paper relates to the last objective of this thesis which is to understand complementarities and differences between product design and service design approaches, as well as to explore to what extent partial PSS infusion can enrich these approaches. The paper develops a multiple case study with 10 design teams using product design and service design approaches. It follows guidelines of ethnographic research (Murchison, 2010) and qualitative research (Charmaz, 2014) to develop and in-depth understanding of the design activities observed, and explore the impact of PSS in the design process of the design teams. First, the paper discusses the main conceptual differences of Product Design, Service Design and PSS design. Second it analyzes these differences empirically with two sets of design team: 5 using a product design approach, and 5 using a service design approach. And finally, it outlines the main changes that have occurred in the design process when PSS approach was infused. The study outlined four main differences between product design and service design, namely in terms of stakeholders roles, design approach versus design object, design context versus design space, and materialization of solutions. Moreover, the study also contributes to understand how PSS was infused in the projects and outlines differences between the two sets. The analysis indicates that design teams using a product design approach infuse PSS in early stages of the design process to broaden their perspective, including more stakeholders in the exploration stage, and developing more systemic solutions in the creation stage of the design process. On the other hand, design teams using a service design approach infuse PSS components in later stages enabling a better preparation to the implementation stage. Together, these three papers contribute to advance PSS design research when it comes to support the design of new product-service system solutions for value co-creation. This research is important and can have an important impact for manufacturing industries and service companies that recognize Service Design and PSS to be potential approaches to tackle socio-technical challenges of our modern and globalized society. Having introduced the challenges, objectives and methodology of the thesis, the following sections present the research papers.

Paper 1: Revisiting PSS and Service Design in the light of the S-D logic1

Abstract

Researchers and practitioners have increasingly recognized the importance of offering value propositions to customers that enable value co-creation as discussed in the Service-Dominant Logic (S-D logic). S-D logic recognizes customers as active co-creators and posits that products and services are only means to an end. Also, different approaches, methods and tools have been developed to design value propositions however they still lack to explicit the S-D logic principles. The design of solutions that provide value-in-use is at the center of both Product Service System (PSS) approach and Service Design (SD). Whereas PSS focuses on designing required functions and aims at sustainability, embedding a more organization-centered approach and problem-solving way of thinking; SD adopts a more human-centered perspective for creative enquiry and focuses on the customer experience, orchestrating interactions between different actors that engage over time, in a complex socio-technological environment. Although SD becomes more established as a discipline, it tends to focus on the early stages of the design process and could further expand its impact if integrated with current organizational innovation approaches. Moreover, PSS design is currently well known in industries and similar principles may be shared among these disciplines. However, so far, these approaches have not been fully integrated. This paper analyses the PSS and SD approaches in light of the S-D logic. It attempts to provide a more comprehensive discussion about these two approaches and proposes a conceptual framework for integrating PSS organizational point of view; and SD human-centered focus to design better service.

KEYWORDS: service design, product-service systems design, service dominant logic

1. Introduction

The recent development of the Service-Dominant logic (S-D logic) literature reframed service and recognized the customers as active actors that integrate and combine

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resources to co-create value (Vargo & Lush, 2014; Vargo & Lush, 2008). From this perspective, customers' roles are evolving from passive recipient to active co-creators of their own service experiences. Although S-D logic contributes to understand the what, how and by whom value is co-created, its high level perspective is difficult to operationalize (Wetter-Edman et al. 2014). Recent development in the Service Design and service innovation literature integrated the premises defined by Vargo & Lush (2008), to form a co-creative and human-centered view of the S-D logic; however such approach remain only partial (Maffei et al. 2005) and could further be integrated with organizational approaches to design new and/or better service. Also, S-D logic posits that value is only determined by customers, in the use-stage of the design process (Vargo & Lush, 2014). As such, companies provide potential value propositions (Grönroos, 2011) and should look for new ways to stimulate longer-interaction with their customers by evolving their design process, business directions and service offerings (Oliva & Kallenberg, 2003), while better incorporating reflections about design thinking practice (Kimbell, 2011a; 2011b). As a consequence of the product-saturated developed world, organizations started to servitize combining services to product offerings (Baines et al. 2007; Baines et al. 2009); and working within larger organizational networks and partnerships (Manzini et al. 2004). The Product-Service System (PSS) approach (Baines et al. 2007), is currently well-known in manufacturing industries and aims to provide functionality and performance to customers through integrated offers. However, organizations acknowledge that they need to better understand what value is, from their customers' perspective (Baines et al. 2009).

Similarly with Kimbell (2011a; 2001b), this paper recognizes that different approaches to conceptualize service design exist and focus on the analysis of two of these approaches and their understanding of design to better incorporate service in industries: the Product-Service System (PSS) organization-oriented approach, and the service design human-centered approach in the framework provided by Kimbell (2011a). Regardless of their distinct roots, PSS and SD characteristics should be further explored in the light of the value co-creation concepts put forward by the S-D logic. Contributions can be two folded: first, the analysis may provide important findings to better understand design and designing within different context. Acknowledging the differences and complementarities of the approaches may provide richer interpretations; and two, verifying the relation of the PSS and SD to the S-D logic can support the

creation of a more unified/integrated vision of the design thinking process that better leverage user- and organizational- co-creation perspectives. To achieve such aims, the paper analyses PSS and SD characteristics, methods and tools; and provides a comparison of the S-D logic value co-creation concepts within those fields.

This paper is organized in five sections. First, a brief introduction to the S-D logic is provided. Then, PSS and SD approaches are reviewed. In section three, the S-D logic concepts are discussed and compared with the design approaches selected. The reflection and discussion section makes an overview of the main results and proposes an integrated view of the PSS and SD approaches with the S-D logic perspective. The last section presents implications for theory and practice.

2. S-D logic as the driver for change

Customers are more demanding and want to find new ways to service their personal needs, either through the means of products or services; to co-create value and reach satisfaction as well (Michel et al. 2008; Manzini & Vezzoli, 2003). Service are expanding worldwide and are claimed to bring economic, marketing and competitive advantages to organizations (Oliva & Kallenberg, 2003). As such, organizations are becoming more interested in incorporating service in their offerings.

For several decades, services have been characterized as different from products. The IHIP was the best known and used model whenever characterizing services was required (Edvardsson, 2005). However, it has been criticized since it describes services according to what they are not; and doesn't reflect what services are in practice (Wetter-Edman, 2009). Moreover service research should focus on differences in how to portray value creation with customers; and not on the differences between goods and services since it limits its potential (Edvardsson, 2005).

2.1. S-D logic

Recent developments in service research and marketing emphasized services' value co-creation nature. For Vargo & Lush (2008) services require the application of specialized competences through deed, processes and performances for the benefit of another entity or for the entity itself; and launched what they called the Service-Dominant logic. S-D logic provided a new root to emphasize the customers' role in co-creating value-in-use

and -in-context, to improve his/her systems' adaptability and survivability by integrating operand (e.g. knowledge and skills) and operant (e.g. products) resources in different ways (Vargo & Lush, 2008).

S-D logic consists of a radical change and fundamental new perspective to value co-creation between service systems (Vargo & Lush, 2008; Vargo et al., 2008). S-D logic attempts to clarify how value is co-created and stresses the importance of the customers' role in the value co-creation process. Vargo & Lush (2014) highlight that customers are always value co-creators, which indicate that organizations per se cannot create value, but rather co-create it with their customers and other actors (stakeholders). Organizations have the opportunity of co-creating value in their customers' sphere of processes and activities (Grönroos, 2011; Vargo and Lush, 2014). As such, firm-focus approach; as the roles and responsibilities in design process must change.

2.2. Towards an integrated approach to explicit S-D logic principles

S-D logic axioms discussed by Vargo and Lush (2014) provide a high level perspective of service however there are some difficulties for achieving implementation (Wetter-Edman, 2009). Recent work attempts to integrate S-D logic guidelines with more practice-based disciplines such as service design (Wetter-Edman, 2014). However, design researchers acknowledge that the creative and human-centered approach of Service Design should find synergies with current organizational innovation approaches (Sangiorgi 2009; Maffei et al. 2005) to have greater impact in companies and further expand the boundaries of the discipline.

Organizations acknowledge that the commoditization of markets makes current differentiation strategies more difficult to maintain (e.g. product innovation, technological superiority, low prices) (Michel et al. 2008), and want to evolve their strategies to compete, adapt and stay relevant. As such, researchers and practitioners developed strategies to servitize companies and their offerings as well. Servitization and the product-service system design (PSS) approach are currently well-known in industries however they acknowledge that value-perception of PSS offerings could better match customers' needs (Baines et al. 2009) and further integrate their experiences. As such, PSS could benefit from the co-creative view of SD and the systemic view of the S-D logic perspective.

3. Approaches to conceptualize Service

This section focuses on analyzing servitization in manufacturing, the PSS design and the Service Design approaches which are concerned with value-in-use for customers; however from quite different perspectives. It analyses the disciplines' backgrounds; as their methods and tools.

3.1. Servitization

Servitization is currently well known in the manufacturing industry; and can be defined as a transition process (Oliva & Kallenberg, 2003; Baines et al. 2009) were companies adapt and systemize their competences; and create value by adding services to their products (Baines et al. 2009) thus providing a combination of components named product-service systems (PSS). Oliva & Kallenberg (2003) assert that organizations evolve their strategies progressively, depending on the product technology and customers' adoption maturity as well (Oliva & Kallenberg, 2003; Kujala et al., 2010). One well-known strategy for servitization consist of consolidating existing product-related services; entering the installed base service market; expand relationship and/or process-centered services and progressively take over end users' operations (Oliva & Kallenberg, 2003). The authors propose a shift from transaction- to relationship-based interaction with customers; evolve contracts from short- to long-term and focus design activities based on the end-user processes and improve product-efficiency and effectiveness. However, it should be noted that general PSS approaches adopted in product-focused industries tend to result on deepening specialized technical knowledge, or developing special competences for operating complex products that would have high costs in terms of operational failure (Tukker, 2004; Tan, 2010), as such the customers' participation in the co-creative activities become less evident. Their problems are framed and established as to-be-solved by organizations.

3.2. Product-service systems background

PSS is closely related with servitization and is defined as products and services combined in a system to deliver required user functionality, or value-in-use, while using resources more efficiently (Baines et al., 2007; Baines et al., 2009). PSS first evolved with a strong environmental and operational mind-set. As such most contributions emerged in journals related with cleaner production and sustainability (Baines et al.

2009; Beuren et al. 2013). There are different types of PSS (product-, use- and, result-oriented; Tukker, 2004). Product-oriented PSS are focused in product plus add-on service offerings (e.g. maintenance, repair); Use- and result-oriented PSS are focused in providing the required functionality or performance to customers. As such in these latter PSS offerings, the product component remains in ownership of the company; whilst customers only pay for the usage or performance. Use- and result-oriented PSS are said to have more potential to reduce environmental impact while bringing higher value to customers.

3.3. PSS methods and tools

Over the past decade several researches on designing PSS have been developed, resulting on methods and tools and contributions of different fields of knowledge to design solutions. As the researchers of PSS come from a typical cleaner operations background, most approaches identified aim to increase products life cycles by adding services and improve product function availability, efficiency and performance when being used in-context (e.g. Xerox paper management system, Rolls-Royce's Power by the hour availability contracts) (Baines et al. 2007).

The Total Care Product (TCP) (Alonso-Rasgado & Thompson, 2006) integrates product and service design process to develop TCP, starting with marketing assessment, concept development, system design, test and implementation (Alonso-Rasgado and Thompson, 2006). The authors propose to use Quality Function Deployment to relate customer needs to product requirement and service attributes; and activities to be undertaken by the company as well. The concept design stage begins once the customer requirements have been ranked, enabling to sketch attributes, functions, product and services. Also service testing is undertaken in the latter stages of the process so customers can have a better idea of the proposed service. They propose a fast-track design process that clarifies the customer-supplier interactions to add value to the product in the early stages of the design process (business ambition, business solution package, core definition of the offering, product modelling; and risk assessment) (Alonso-Rasgado & Thompson, 2006).

The MEPSS method proposed by van Halen et al. (2005) is a systematic and strategic method that starts by analyzing the company's resources and, progressively, tries to

eliminate "waste"; and identify the most promising alternatives to optimize the product-use by engineering and system behavior analysis. Similar with the TCP, the MEPSS' main stages consist in making a strategic analysis, exploring opportunities, develop ideas, develop the PSS solution; and prepare for launch (Halen et al., 2005).

Although these approaches have their merit, they tend to emphasize the good-dominant logic for designing solutions; and reflect the dyad relationship of customer and suppliers. Customers' role tends to focus on providing insights; or testing solutions, which also was interpreted as limitative. Later PSS research acknowledge customers' acceptance of PSS as a challenge. Rexfelt & Örnas (2009) developed a method based on activity theory that aims to inform about the customers' perception of PSS solutions to reduce uncertainties regarding acceptance. Their framework consists in understanding desirable and undesirable activities. PSS solutions are refined according to what customers want to be enabled to or relieved to do. Although the approach has the merit of observing customers more closely, they are still viewed as providers of insights or testers.

Also, authors emphasize that current PSS approaches may tend to result in cutting-edge technology (product and process optimization) but PSS radical innovation shouldn't necessarily lie in techniques but rather in the way more-or-less existing technologies can be systemized (Manzini & Vezzoli, 2003). Other contribution coming from the service design field suggest to analyze PSS from a more systemic approach; and propose collaborative approaches (build and reconfigure partnerships) to use resources more efficiently, throughout product's life cycle (Manzini & Vezzoli, 2003; and Manzini et al., 2004; Morelli, 2002; Morelli, 2006). Manzini & Vezzoli (2003) identify three classifications for PSS evolution: services providing added value through product life cycle; services providing final results to customers; and enabling platforms for customers (e.g. car sharing). Also, Morelli (2006) focuses on the service-network component to the PSS field. The proposed tools identified aim to design alternative scenarios (map of network of actors, hypothesis generation; and use cases) and the resources required for successful solution delivery (stakeholders' matrix) (Morelli 2006). The focus of this work however, is on analyzing service stakeholders (or actors) and their capabilities, rather than on the integration of customers' experiences, resources and requirements in the design process.

Overall, PSS design methods tend to reflect a dyad relationship between customers and suppliers. Despite later research emphasizing an actors' constellation perspective to design solution, the customers' experiences, resources and requirements can be further integrated in the design process to design better product-service solutions, and systematize the process to design for value co-creation as well.

3.4. Service Design background

SD is defined a multidisciplinary, creative, human-centered discipline focused on analyzing, envisioning, designing and iteratively refining the quality of a service by analyzing and designing the interactions between its tangible and intangible elements (product, technologies, people, and structures) to create alternatives ways-of-doing (Manzini 2009), bringing ideas to life (Patrício & Fisk, 2013) and transform determined situations into preferred ones (Simon, 1969). SD is a discipline that slowly evolved from the interaction design and established itself as an ordinary practice (Holmlid, 2009); and now merges design disciplines (interaction design, product design, design ethnography) with service management, marketing, operations (service backstage) and information systems (Patrício & Fisk, 2013). The discipline is broadening its scope and deepening its knowledge; and has developed tools and methods that explore actor-to-actor, actor-to-system; and system-to-system interactions (Sangiorgi, 2009). SD adopts a fundamental user-centered and participative approach to design for service (Holmlid, 2009); and has been developing methods and tools to better reflect customers' experiences in the design process. The next paragraphs discuss some of those methods.

3.5. Service Design methods and tools

Service Design is a discipline steamed from practice and has evolved methods and tools able to express important characteristics that facilitate, through creative and visual-thinking tools, the prototyping, test and refinement of service experiences (Stickdorn & Schneider 2012). Scenarios, storyboards, customer journey, use case, persona, experience prototype, among other tools contribute to visualize and test the service experience from the user point-of-view and to understand the detailed specifications required for co-creating experiences (Stickdorn and Schneider 2012). Also, other works on SD focuses on customers' experience and system perspective.

Teixeira et al. (2012) propose the Customer Experience Modelling method (Teixeira et al. 2012) to represent the different aspect of the customer experience through a diagrammatic representation. It enables to understand customers' experience by integrating and providing a holistic view of customer's flow of activities, contextual elements (artefacts, services and systems) and requirements. Also, by focusing on the analysis customers' tasks and operations through Activity Theory (Mickelsson, 2013); and understanding of customers' experiences, problems and needs, the Multi-level Service design (MSD) Method (Patrício et al., 2011) improves the connection between customers' experience and SD components in three levels: the service concept (what is the offering), service system (which resources are needed) and service encounter (how are they connected) (Patrício et al., 2011).

Service concept definition evolved to reflect more than the supplier view of the service (core and supplementary service); to encompass a network of actors that exchange service-for-service to provide benefits or value (Vargo & Lush, 2014). Although the service concept is a central aspect of service design, there is a limited attention regarding a practical design method to define it (Goldstein, 2002).

Also, SD is defined as partial approach (Maffei et al., 2005; Alonso-Rasgado & Thompson 2006) and tends to focus on the early stages of the design process (Yu & Sangiorgi, 2014). To be effective and further expand in industry, it should be integrated with existing organizational contemporary innovation perspectives (Maffei et al., 2005) to form a coherent approach to design value propositions for value co-creation.

4. Comparing S-D logic concepts in PSS and Service design literature

As mentioned earlier, the S-D logic axioms defined by Vargo and Lush (2014) clarify the nature of value co-creation; and four fundamental concepts extracted from those axioms can be further discussed: value, co-creation, resource integration; and actors and service systems' roles. This section discusses the concepts and reflects on how they echo on PSS and service design approaches.

4.1. Value

In S-D logic value is only determined by the beneficiary of the service (Vargo & Lush 2004). Value is the result of an interaction between customers with a service that

translates into being or feeling better off than before (Grönroos, 2011). In PSS literature, value is determined in terms of value-in-use (Baines et al, 2007). As explained in the previous chapter, PSS' offerings focus in delivering performance and functional value (Sandström et al., 2008) as efficiently as possible (Baines et al. 2009). Moreover, other types of value (mental value as explained in Grönroos, 2011; Sandström et al. 2008) are less evident in PSS design. In SD, the value emerges as a result of a service experience which is determined from the customers' point-of-view (Meroni & Sangiorgi, 2011). SD attempts to capture knowledge about customers' emotions and activities as well (Mickelsson, 2013; Wetter-Edman et al, 2014; Meroni & Sangiorgi, 2011) to better understand individuals' experiences and qualities (Wetter-Edman et al, 2014) which shape their perception of value. SD is inspired from that information to co-create new propositions.

4.2. Co-creation

S-D logic posits that value is co-created between different actors and service systems; and that customers are always part of the co-creation process (Vargo & Lush, 2014; Vargo et al. 2008). As such, companies can only make potential- value propositions that may become real-value if used in-context by customers (Vargo & Lush, 2014; Grönroos, 2011). In PSS literature, co-creation is not used explicitly. It may be used to refer to customers' participation in ideation sessions or workshops, to share ideas and insights in the early phases of the design process; or testing/refining the solutions. Also, PSS focus on functionality and performance tend to result in approaches focused in optimizing life cycle analysis; engineering and delivery processes; stakeholders' reconfiguration which are design activities that may not require involving customers. Similarly to S-D logic, SD approach adopts a fundamental human-centered perspective. It evolved participative techniques such as card games, role playing, and narratives, among others (Stickdorn & Schneider, 2012) to engage in a dialogue with customers and bring their experiences to the creative process (Wetter-Edman et al., 2014). Recent studies suggested customer participation to extend beyond the service process, involving them in learning and experimenting; engaging in active dialogue, collaboration, co-development with sellers (Mustak et al. 2013). As such, SD approach considers customers as active co-creators of their own experiences and empowers them through participation (Wetter-Edman et al. 2014).

4.3. Resource integration

S-D logic posits that value is co-created through resource integration. Actors can co-create value by applying both skills and knowledge on products, services or systems to exchange service-for-service (Vargo & Lush, 2014). PSS literature tends to focus on the analysis and reconfiguration of organizational competencies (e.g. stakeholders' map); and the combination of products and services (resource integration) to deliver value. As such PSS still somehow, considers that static resources embedded with "frozen knowledge" that producers create and deliver which reflects the dyad interaction between firm and customers (Michel et al., 2008; Vargo & Lush, 2014). In SD approach resource integration happens during the use- and designing stage as well. It focuses on peoples' lives and problems to stimulate their willingness to integrate their resources; engage in the co-creation and co-production process to image future systems (Wetter-Edman et al. 2014). It also aims to increase their resourceness (Grönroos, 2011), which is their ability to use the resources they have available to co-create value.

4.4. Actors, systems and roles

In S-D logic, actors are all resource integrator (Vargo & Lush, 2004). PSS adopts an organizational constellation perspective. Stakeholders' motivation matrix; actors network (Morelli, 2009) techniques; or the Solution-oriented Partnership Methodological Framework (Manzini et al. 2004) are useful to understand the customers' situation, which partners may participate in the design and delivery of solutions, what is expected from them; and exploration of solution platforms. However, those solutions may not always result in more active customers. Solutions may enable or unable them to take action (Rexfelt & Örnas, 2009; Michel et al. 2008). SD acts upon a continuum where customers' participation evolves from consultation to active co-production activities (Wetter-Edman et al., 2014) and become conscious and active participants of the SD and delivery processes (Meroni & Sangiorgi, 2011). Recently in SD literature, the term user-centered, progressively evolved to human-centered design to consider the role of larger network of actors which go beyond the user (Meroni & Sangiorgi, 2011).

5. Reflection and discussion

This section analyses overlaps and differences, and presents an integrated framework to design for value co-creation.

5.1. Main overlaps and differences

The previous chapter described how S-D logic concepts were understood in PSS and service design literature. Table 1 provides an overall comparison of the design approaches. As discussed, both approaches are concerned with the value-in-use for customers; however it echoes from different points-of-view.

	Service design	PSS	Overlaps Service Design / PSS	
Value	Value is defined as the result of a memorable service experience to customers	Value is defined in terms of value-in-use; focused in offering outputs (functions), while using natural resources more efficiently	Both are concerned with value-in-use. Whereas Service design focuses on the human component (emotions); PSS focuses on the functions provided	 *no overlap*
co-creation	Customers actively participate in the design process; they are considered fundamental	Co-creation occurs within organizational value networks; and may or may not include customers	Both are concerned with customers participation in the design process; however the purpose of service design is to empower; whilst in PSS is to serve (may lead to more passive customers)	 *somewhat overlap*
resource integration	Encourages customers to reflect upon, develop and use their own activities, knowledge and skills; and enable them to act in-context	Acknowledges the competencies of the value network from an organizational perspective; integrates operant resources (products, softwares) to create the offering	PSS tends to focus on competencies from a organizational perspective and *objectified* resources; service design studies customers' skills and knowledge (people's resources) to co-design and co-create future systems	 *slightly overlap*
actors and systems' roles	Studies users/customers activities, and interactions within their socio-technological world; attempts to empower them and develop more active roles	Organizatonal networks provide more-or-less integrated offers that may or may not require customers to be more active	Both acknowledge the complexity of networks; PSS organizational approach to design offerings may or may not take over some of the customers' activities; which may lead to less active customers	 *somewhat overlap*

Table 1. Comparison between PSS, S-design approaches through the S-D logic

For PSS, value is about delivering a function (Baines et al. 2007); whilst in SD, the focus in on providing usable as well as pleasurable experiences (Wetter-Edman et al. 2014). Co-creation somewhat overlaps since customers are considered in the design process of both approaches; however PSS aims to analyze customers to better serve them; whilst SD aims to empower. Resource integration in PSS starts with a more strategic and organizational perspective. After defining the function-to-be-delivered, PSS studies networks competencies; and sort of leans the product-service production and delivery processes to design an efficient system. The SD approach starts with people's experiences, activities; as well as their beliefs and dreams to increase their willingness to integrate their own knowledge and skills. S-D logic considers actors are

all resource integrators. PSS adopts a partnership perspective, where predefined partners join efforts to tackle customers' problems; however the solutions may not always result in enabling platforms for customer. SD considers users as humans in context; that should be enabled and empowered to better serve themselves. In SD, actors are conscious and active participants.

5.2. Presenting an integrated framework to design for value co-creation

Further integration is required to better support the integration of product and service components, business processes and activities between actors and networks. PSS can be developed with different focus on business decisions, product planning and life cycle; and detailed design. As such, while designing PSS four levels should be considered (Tan, 2010) (figure 1). Also three dimensions of SD were identified (figure 2).

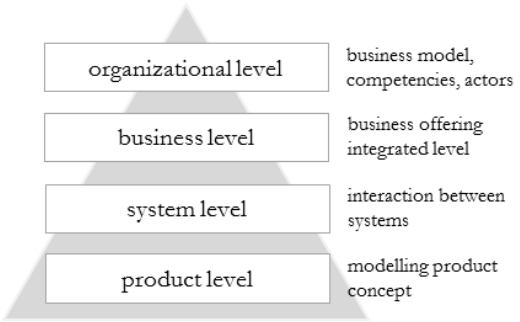

Figure 1. Dimensions to be considered whilst designing with a PSS approach (adapted from Tan, 2010)

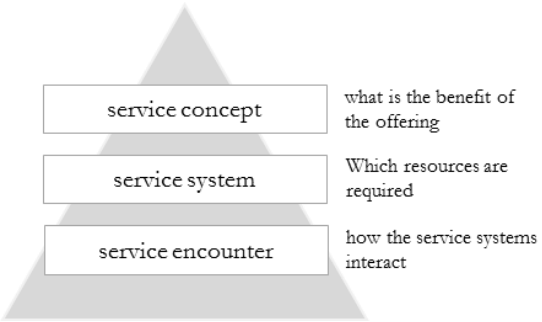

Figure 2. Dimensions to be considered whilst designing with a Service design approach (adapted from Patrício et al. 2011)

The framework presented in figure 3 attempts to better integrate the different contributions discussed so far; and is further discussed below.

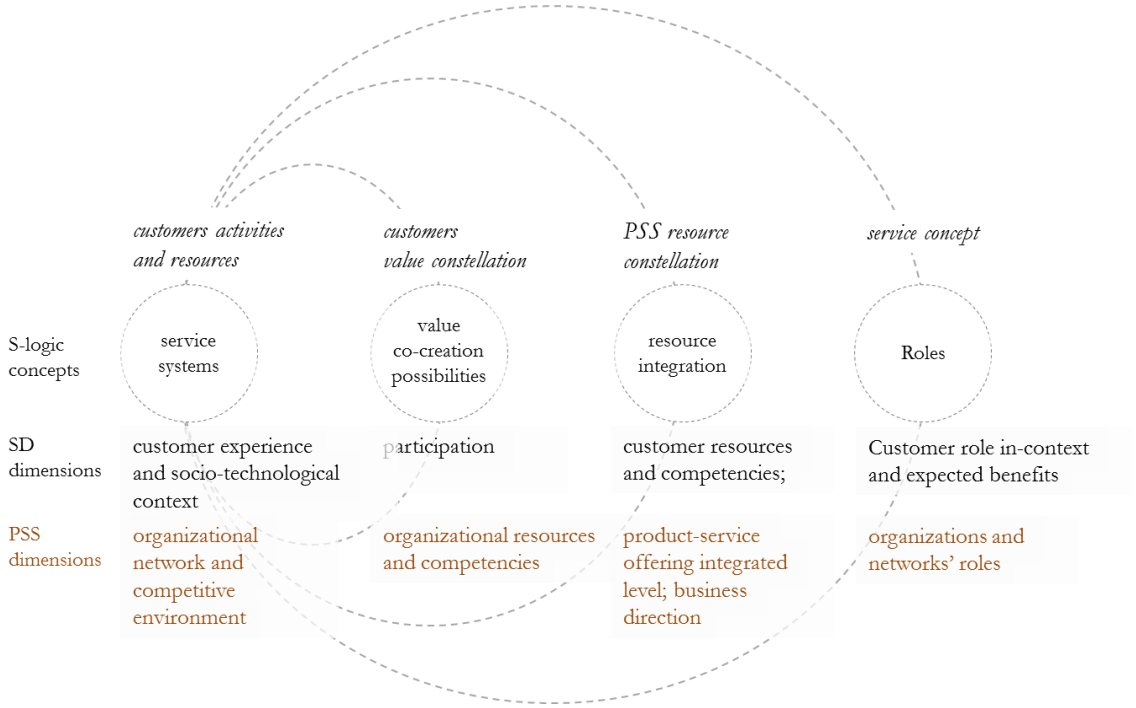

Figure 3. Proposed integrated approach for S-logic implementation

Explore systems and customers' resources

The framework proposed starts by understanding customers' context, activities, experiences, problems; and resources they have and how they use them. The initial stage is an important not only to reflect upon resources but also in resourceness (Grönroos 2011; Vargo & Lush, 2014) of customers as well (their ability to apply what they know to what they have available, to improve their well-being).

Understand and envision new value constellations

Customers can contribute with more than just "insights" for product/service development or usability test for evaluation of an offering. SD considers customers as "experts of their own experiences" (Sander & Stappers, 2008); as such they should be enabled to reflect on their own experiences through participatory and co-creation approaches (e.g. design probes, design games, storytelling, narratives). Customers will share knowledge based on what they have already experienced, and should be asked to share the expected outcomes of the new solution from their point-of-view (Ulwick, 2002; Verganti, 2013). Organizations specialized knowledge should complement customers' resources; what if scenarios or prototypes should be stimulated to provoke divergent thinking.

Explore PSS resource constellation

S-D logic removed the need to distinguish between products and services; and instead proposed to look at solutions as a form of value-in use however such perspective requires to be operationalized. The PSS resource constellation is the interplay between value-in-use as defined by customers, and how they might be realized through means of operand or operant resources (product, services or systems). Customer, organizations and beneficiaries of the solution integrate their resources and competencies; the integration level of the offering, such as the business directions is discussed. Companies can provide more-or-less integrated offers depending on the activities that customers want to be enabled or relieved to do. New tools should be developed to further integrate customers' and organizations' resources; and explicit actor's roles.

Define service concept

At this stage, the service concept is defined. In S-D logic, actors are all part of service production and delivery processes for value co-creation. As such, designing requires active collaboration between actors. The expected benefits and roles should be clearly defined for both organizational network, and for customers as well. Customers can expect more benefits within network if provided value propositions that enable value co-creation. As such, more than continuous refinement of efficiency, companies should work more collaboratively; and enable adaptability within networks.

6. Conclusions

PSS and SD approaches have different origins but are both concerned with value-in-use. As such their characteristics, gaps and complementary were discussed and a conceptual framework was presented. The framework hopefully contributed to better understand how to provide a higher integrated systemic value to customers though efficient resource integration (products-services and knowledge) and in ways that could be more meaningful for both organizations network and customers. In the framework presented, S-D logic enables to better understand what is value; how it is created and by whom. SD participatory and human-centered approach allows to better understand and involve customers in the design process, enabling them (and organizations as well) to understand how their competencies can co-create value in meaningful ways. Finally PSS provides the organizational and business perspective of solutions. PSS allows

operationalizing the principles of the S-D logic and service ideas of SD into concrete products and services, from an integrated perspective.

Industries have long been working on transactional-interactions with their customers. As such their design process reflects a one-way road, with some feedback loops, when it comes to testing the solutions (e.g. user as tester and provider of insights in the later stages of the design process). Moreover, service literature tends to focus on analyzing and evaluating services in isolation or from a dyad perspective (van Riel et al., 2013; Jaakkola et al., 2015); as such further studies are required to analyses and propose new organizational' product-service design approaches when it comes to designing product-service system offerings to enable value co-creation.

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Paper 2: Bringing service design to manufacturing companies: integrating service design and PSS design approaches[2]

Abstract

Manufacturing companies increasingly try to innovate in their offers to consumers by creating more complete solutions that combine product and service components. However, shifting from a product-centric perspective to a solution-oriented perspective is challenging. The present study adopted a design research methodology and built on Service-Dominant logic, integrating the human-oriented perspective of Service Design with an organizational network-oriented perspective of Product-Service System. It creates a new Integrative PSS approach, evolves design models, and provides an application in a manufacturing industry. This paper details how the application supports the design of product-service system solutions from the exploration to the implementation stages, highlighting the physical evidence of service, and contributes to advance design research at the intersection of PSS and Service Design.

Keywords: Service Design, Product-Service Systems, Design Methodology, Design Research

Introduction

To address globalization and rapid technological development, manufacturing companies attempt to integrate services in their product offerings to create more complete solutions (Baines, Bigdeli, & Bustinza, 2017; Gebauer, Gustafsson, & Witell, 2011). This transition, known as servitization, consists of shifting the business from selling products to offering product-service system solutions (Oliva & Kallenberg, 2003). Product-service system solutions are bundles of product and service components intended to co-create value-in-use for customers (Baines, Lightfoot, Benedettini, & Kay, 2009) and are usually supported by organizational networks (Beuren, Gomes Ferreira, & Cauchick Miguel, 2013).

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Rolls-Royce (pay power-by-the-hour) and Xerox (copier service management system) have developed successful solutions that are cited frequently in the servitization literature (Baines et al., 2007; Kowalkowski, Gebauer, Kamp, & Parry, 2017). In these particular cases, the manufacturers remain the owners of the physical product, take responsibility for the performance and disposal of equipment, and make efforts to improve the efficiency of the overall technical product-service system solution. However, to take advantage of the servitization process, manufacturing companies would benefit from a more widespread transition to integrated goods–service solutions (Ostrom, Parasuraman, Bowen, Patrício, & Voss, 2015).

Service Design offers a holistic, human-centered, co-creative approach to developing new services (Meroni & Sangiorgi, 2011; Sangiorgi, 2009; Wetter-Edman, Sangiorgi, Holmlid, Grönroos, & Mattelmäki, 2014). This approach is multidisciplinary, incorporating contributions from design, interaction design, service marketing, among others (Patrício & Fisk, 2013). Service Design employs an iterative process (Holmlid & Evenson, 2008) to analyze and orchestrate interactions between different types of socio-material elements (Kimbell, 2011), with a special focus on the service interface and customer experience (Secomandi & Snelders, 2011).

Recent advancements in Service Design have incorporated Service Dominant logic (S-D logic) (Wetter-Edman et al., 2014), according to which organizations do not pre-produce value but strictly offer value propositions that customers convert into value through usage (Chandler & Lusch, 2015; Vargo & Lusch, 2016). Customers are always co-creators of value by integrating the company's offerings with their constellation of resources, including personal capabilities. For example, in health care, patients integrate the service offerings from hospitals with their own network of resources and co-create value to stay healthy. This perspective has influenced Service Design and led to the development of service offerings that facilitate customer value co-creation processes (Meroni & Sangiorgi, 2011; Wetter-Edman et al., 2014).

PSS and Service Design approaches offer complementary perspectives, but further integration is needed. On the one hand, PSS approaches support the design of product-service solutions within the manufacturing industry (Baines et al., 2007). However, PSS approaches rooted in cleaner production (Boehm & Thomas, 2013) have led to a firm-

centric perspective focused on creating more efficient and environmentally sustainable product-service system solutions that tend to overlook the customer experience (Stacey & Tether, 2014; Valencia, Mugge, Schoorman, & Schifferstein, 2015). Some PSS design perspectives have been used to develop a more systemic analysis of service networks by considering product-service system solutions as the result of a social construction linking technological artifacts with relevant social groups, such as organizations or local actors, in order to co-create solutions (Morelli, 2002, 2006; Morelli & Götzen, 2016; Morelli & Tollestrup, 2009). Developing novel product-service system solutions, therefore, has the potential to enable higher value-in-use and to enhance the competitiveness of manufacturing companies. However, for this potential to be realized, PSS development should enable firms to better address customer experience and emotions (Stacey & Tether, 2014). To do this, firms must understand how customers co-create value by integrating the product-service system offering with other resources in their value constellations (van Riel et al., 2013).

On the other hand, Service Design offers a holistic and co-creative approach to innovating services that includes understanding the experiences of customers and service providers in their contexts and translating these insights into new service system interactions and possible service futures (Holmlid & Evenson, 2008). However, this approach lacks the organizational network component that enables the operationalization of the service concepts (Morelli, 2009). To co-create integrated solutions in manufacturing contexts, the Service Design and PSS approaches require better coupling. This is especially important at later stages of the design process for operationalizing the service system and the organizational network to enable the desired customer experience (Bailey, 2012; Junginger, 2014; Pirinen, 2016; Yu & Sangiorgi, 2014).

The aim of this research was to build on S-D logic and combine PSS and Design to develop an integrative PSS approach to support manufacturing companies in their servitization process. The remainder of this article is structured as follows. In the following section addressing the theoretical foundations, previous research on PSS and Service Design is analyzed, identifying complementarities and knowledge gaps. The methodology section describes the design research approach adopted for developing, applying, and validating the integrative PSS approach. The subsequent sections present

the integrative PSS approach and its application to create new integrated solutions, showing how it supported a particular manufacturing company's journey toward servitization. The final sections discuss the contributions of this research and present the conclusions and future research directions.

1 Theoretical foundations

1.1 Product Service System (PSS) design

Product-service systems solutions are the result of a servitization process within manufacturing companies that infuses service to differentiate product offerings (Gebauer et al., 2011; Oliva & Kallenberg, 2003). The PSS approach is also a strategy for innovation that shifts the business model from selling products to offering combinations of products and services that are jointly capable of fulfilling specific customer needs and delivering value-in-use (Baines et al., 2007). Therefore, product-service system solutions are value propositions oriented toward delivering value-in-use to customers, as opposed to providing products alone (e.g., mobility as opposed to selling cars or thermal comfort as opposed to boilers). This servitization process may result in a continuum of solutions with different levels of product and service infusion (Tukker, 2004).

If conceived properly, product-service system solutions have the potential to decouple material consumption from economic growth, especially in the case of ownerless solutions (Baines et al., 2007; Manzini & Vezzoli, 2003). Ownerless solutions (use- and result-oriented solutions in particular) (Tukker, 2004) imply a change of roles: manufacturers retain ownership of the product component of a solution and make it available for customers, while customers pay for the use of the product (e.g., bike sharing service), its performance (e.g., engine power), and/or results (e.g., washed clothes). This provides incentives for manufacturers to extend the life cycle of products, leading to goal-based optimized approaches (Ceschin & Gaziulusoy, 2016) focused on economic and environmental dimensions (for an overview, see Cavalieri & Pezzotta, 2012; Vasantha et al., 2012). The aim of such solutions is to enhance the efficiency and performance of the technical system and adopt a firm-centric perspective (Aurich, Fuchs, & DeVries, 2004; Hara, Arai, Shimomura, & Sakao, 2009; Maussang, Zwolinski, & Brissaud, 2009). Such efforts represent important advancements for PSS

development, but are they are focused on production aspects, thus neglecting customer experience and emotions (Stacey & Tether, 2014), which are key to the acceptance of PSS offerings (Rexfelt & af Ornäs, 2009).

Other PSS design approaches adopt more social, systemic, and network-oriented perspectives (Manzini, Evans, & Collina, 2004; Morelli, 2002, 2003; van Halen, Vezzoli, & Wimmer, 2005). Morelli (2002, 2006) developed a design exploration process focused on understanding and combining service networks and their capabilities. In particular, the Actor Network Map provides an overall picture of the network of stakeholders involved in a system, emphasizing their direct and indirect relationships, influence, roles, and functions. In addition, the Stakeholder Motivation Matrix portrays the motivations and benefits of stakeholders taking part in a product-service system solution (Morelli & Tollestrup, 2009). Lastly, the Stakeholder System Map visualizes the stakeholders involved in the design, production, and delivery of a particular offering, emphasizing their interrelations (van Halen et al., 2005). These methods support the development of integrated solutions that are based on partnerships among organizational networks, thus facilitating the implementation.

In contrast to the systemic and network components of PSS, contributions from interaction design within PSS focus on the visualization of contextual components from a more local perspective, such as Contextual Design Analysis (Beyer & Holtzblatt, 1997). For example, the Flow model depicts different actors' roles and responsibilities within a determined local context. The Artifact model emphasizes the characteristics of physical evidence, whereas the Physical Space model emphasizes how the spatial environment influences actions.

The combination of Contextual Design Analysis and the more systemic and network-oriented approach of PSS provides significant support for the development and implementation of product-service system solutions from an organizational perspective. However, better incorporation of customer experience and value co-creation processes is needed (Bertoni, 2013) to make a more comprehensive connection between the organizational network and customer experience components of value co-creation (Morelli, 2009). The complexity of customer experience and rapid evolution of technology lead to increasing numbers of interactions (Breidbach & Maglio, 2016). In

this context, technology, actors, products, and processes within systems constitute heterogeneous socio-material components (Kimbell, 2011) that need to be considered to develop a more integrated design for product-service system solutions.

1.2 Service Design

Service Design is a multidisciplinary, human-centered, participatory approach (Holmlid, 2009; Meroni & Sangiorgi, 2011) that brings new service ideas to life (Ostrom et al., 2010). Service Design provides methods and tools for orchestrating and materializing interactions between people, institutions, and technological systems in innovative ways (Teixeira et al., 2017). In comparison to PSS, which focuses on the design of product-centric solutions (Baines, Lightfoot, Peppard, et al., 2009), Service Design takes a more holistic stance, exploring the different touchpoints of the customer journey (Clatworthy 2011) to identify opportunities for co-creating value (Yu & Sangiorgi, 2014). Service Design explores customer activities and identifies opportunities to orchestrate new service processes and service interfaces (Secomandi & Snelders, 2011). It also provides visualization tools that support participation and collaboration among different stakeholders (Holmlid, 2009; Holmlid & Evenson, 2007). For example, Customer Experience Modeling (CEM) systematizes the understanding of customer experience through visual representations of customer activities and their contextual elements (Teixeira et al., 2012). This understanding of customer experience supports Multilevel Service Design (Patrício, Fisk, e Cunha, & Constantine, 2011) that aligns the service concept with the Customer Value Constellation, the service system with the service system architecture, and the service encounter with the Service Experience Blueprint.

Both the Service System Architecture and the Service Blueprint distinguish between frontstage and backstage activities, depicting how customer activities are supported by different service interfaces and backstage processes (Bitner, Ostrom, & Morgan, 2008; Patricio, Fisk, & Cunha, 2008). However, these Service Design models do not provide a detailed view of how the physical components and the organizational network must support the desired customer experience at the frontstage. This outside-in approach for service innovation is important for human-centered Service Design. However, further integration of the physical components and the organizational network is needed to support manufacturers in their transition to PSS design and to develop high value integrated product-service system solutions.

1.3 Service-Dominant logic (S-D) logic and Service Design

Service-Dominant (S-D) logic is a key pillar of Service Design, as it provides a framework for understanding service systems in action (Wetter-Edman et al., 2014). Service systems are configurations of people, technologies, and other actor constellations and resources that interact with other service systems to create mutual value (Chandler & Lusch, 2015). According to S-D logic, service is the application of resources for the benefit of other entities (Vargo & Lusch, 2004, 2008). From this perspective, customers are always co-creators of value, and firms can only make value propositions, which customers turn into value through usage (Lush & Vargo, 2014). Value propositions are invitations to customers and other actors to engage in service, and they play a key role in initiating stakeholder communications (Chandler & Lusch, 2015). S-D logic brings a customer-oriented view, where providers play the role of facilitators of value co-creation. Thus, service providers' offerings are value propositions that customers integrate within their constellation of activities and experiences (van Riel et al., 2013). Furthermore, as value is not embedded in things but is co-created, it is fundamentally experiential, individual, and contextual (Heinonen & Strandvik, 2015; Heinonen et al., 2010). Value co-creation, therefore, goes beyond the dyadic interaction between the customer and service provider and involves multiple interactions between customer networks and provider networks (Gummesson, 2007; Sweeney, Danaher, & McColl-Kennedy, 2015).

S-D logic provides an important foundation for Service Design due to its customer-oriented view, which understands value as the result of an experience (Jaakkola, Helkkula, & Aarikka-Stenroos, 2015). Based on this framework, Service Design becomes key in planning the conditions to enable and facilitate value co-creating interactions and relationships to take place in the future (Wetter-Edman et al., 2014). In addition, by focusing on interactions and placing customers at the center of the design process, physical goods and services become a pool of supporting elements that customers select and integrate within their practices to co-create value (Kimbell, 2011; Meroni & Sangiorgi, 2011; Patrício et al., 2011).

This Service Design perspective is fundamentally different from traditional PSS, as the effort of the former is focused on understanding customers' culture (norms and values) and practices through participation and engagement throughout the design process

(Holmlid, 2009; Sanders & Stappers, 2008; Trischler, Pervan, Kelly, & Scott, 2017). This approach enables mutual learning and the formation of new relationships, as opposed to focusing on the barriers, strengths, and internal processes of the company and how to change them (Payne, Storbacka, & Frow, 2008). In this context, using S-D logic to integrate PSS and Service Design is important for leveraging product-service system solutions in manufacturing companies. The progressive transition to PSS design for value co-creation requires accepting that the company and its solutions can only influence the value co-creation process, which occurs within the customer sphere and cannot be entirely predicted (Grönroos, 2011). It also requires looking at resources as potential value and not as value per se. So far, the organizational perspective has underpinned PSS methods and tools to define production processes and uses of resources, but a service perspective can leverage PSS design for value co-creation with different network actors (Morelli & Götzen, 2016).

1.4 Integrating PSS and Service Design approaches

A review of the literature reveals differences as well as complementarities between PSS, Service Design and S-D logic. A PSS organizational network-oriented approach supports designing and implementing product-centric solutions while considering services in the design process (Baines, Lightfoot, Benedettini, et al., 2009). However, this approach is usually aimed at improving the efficiency and performance of technical systems and does not focus on enhancing the customer experience (Stacey & Tether, 2014).

The objective of Service Design aims to envision and materialize new human-centered service value propositions. It relies on understanding customers' experience, interactions, practices, and dreams (Meroni & Sangiorgi, 2011). In this context, Service Design can provide a complementary human-centered perspective to co-create new product-service system solutions. S-D logic provides a broader understanding of value co-creation within service systems (Lush & Vargo, 2014) that has been adopted by Service Design. Value is not only co-created dyadically but is a multi-actor phenomenon. Customer value co-creation processes are influenced by wider service systems that extend beyond the firm's line of visibility and control (Grönroos & Voima, 2013).

PSS design adopts an organizational network perspective, but can be enriched by S-D logic and Service Design which views the customer as a key co-creator of value (Costa, Patrício, & Morelli, 2016). In this context, we propose using the perspective of S-D logic to integrate the PSS and Service Design approaches and evolve their methods, as illustrated in Figure 1. This new integrative PSS approach can help organizations develop a clearer view on how they can integrate their resources within customer value constellations. This approach brings together the operational network-oriented view of PSS and the human-centered, co-creative Service Design approach to transform a business through innovative forms of value co-creation.

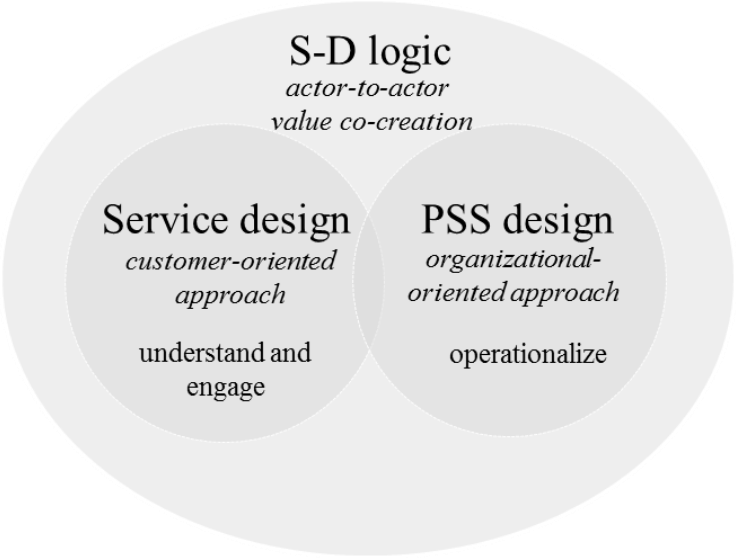

Figure 1. Integrated perspective of PSS, Service Design and S-D logic

2 Methodology

Design research provided a suitable methodology for integrating PSS and Service Design and evolving design methods and tools to support the co-creation of integrated solutions. Design research is concerned with artificial, as opposed to natural, phenomena (Buchanan, 2001; March & Smith, 1995). In the area of PSS, the purpose of design research is to develop new design knowledge that can be embedded in the configuration of design artifacts (Cross, 1999; Zimmerman & Forlizzi, 2008), and it emphasizes the construction-oriented view of designing, building, and reflecting upon the use of these artifacts (Fallman, 2008; Forlizzi, Zimmerman, & Evenson, 2008). Design artifacts can either be new methods, tools, or models (Sein, Henfridsson, Purao, Rossi, & Lindgren, 2011). Hence, design research is focused on creating something new

in a planned and reflective iterative process, and studying dynamic phenomena by looking at the design context, actors involved, design process, and methods used to solve problems (Dorst, 2008).

Design research can be viewed as comprising two main activities: (1) building new design artifacts and (2) reflecting upon the artifacts and their use in context (Manzini, 2008). The first activity is aimed at identifying opportunities for knowledge creation, which are important for building design theory and are also relevant for design practitioners (solving a determined class of problems, which is exemplified through a specific instantiation). This provides a foundation for generating new design artifacts. The second activity entails intervening in a relevant context. While the design practice generates new solutions, design research reflects upon the usefulness and performance of design artifacts previously created to solve the class of problems identified (Fallman, 2008).

Researchers are encouraged to combine other methods to improve the rigor of design research (Blessing & Chakrabarti, 2009; Friedman, 2003; Yee, 2010). Design Science Research, with roots in engineering design and information systems, can provide a complementary perspective in this regard. Design Science Research concentrates on understanding the context of organizational phenomena and creating and evaluating artifacts that solve organizational problems (Hevner, March, Park, & Ram, 2004), and it is spreading in the service research field (Teixeira et al., 2017). Similar to design research, Design Science Research comprises activities focused on building and applying new artifacts, but includes a third activity—that is, evaluating the artifacts created. Therefore, to improve the robustness of the research, we built upon design research and complemented the research process with the evaluation stage from Design Science Research (Hevner et al., 2004). We also used the interaction design research criteria of process, relevance, usefulness, and extensibility (Forlizzi et al., 2008) to assess the research contribution of the integrative PSS approach.

Following guidelines for design research and Design Science Research, the research process followed in this study iterated between three main stages: (1) conceptual development of design artifacts, (2) application of the design artifacts in a manufacturing context that exemplifies the relevant class of problems (supporting

traditional manufacturing companies to co-create product-service solutions), and (3) evaluation of the design artifacts developed.

(1) Conceptual development: The research began with the conceptual development of the design artifact, based on a review of the literature on S-D logic, Service Design and PSS design (section 2). The analysis provided the theoretical foundations for the conceptual development of the integrative PSS approach (section 4). The differences and complementarities of these perspectives were analyzed and a new integrative PSS approach and models were created in accordance with analytical conceptual research (Meredith, 1993).

(2) Application: After the conceptual development stage, the new integrative PSS approach was applied in the context of a manufacturing company. This application was intended to test, evaluate, and evolve the integrative PSS approach and design models in an iterative process. The application was undertaken with a company that designs and manufactures laboratory equipment and furniture. This provided knowledge to further develop and refine the integrative approach (theoretical contribution) and support the company in its design of new, integrated solutions (practical contribution). This stage involved a six-month research project to develop new smart laboratory product-service solutions with the company.

The research team collaborated with the company and was responsible for introducing the new integrative PSS approach into the company's regular development process. This involved introducing the integrative PSS approach including its process and models in the different design stages (Buchanan, 1992; Dorst & Cross, 2001; Johansson-Sköldberg, Woodilla, & Çetinkaya, 2013). Overall, the application of the integrative PSS approach involved internal workshops with the company and weekly meetings with the design team, visits to laboratories, participation in exploration and co-design sessions with stakeholders, one prototype and testing session, and one internal workshop that was undertaken with the development team, as detailed in Table 1. A qualitative research approach was adopted in the exploration phase—namely, the tenets of the sample design, data collection, and data analysis—to gain an in-depth understanding of the customer experience (Charmaz, 2014; Neuman, 2014; Strauss &

Corbin, 2015). Further details about the qualitative research process are provided in the application section.

(3) Evaluation: Finally, the evaluation of the integrative PSS approach followed Design Science Research guidelines (Hevner et al., 2004) and design research criteria (Forlizzi et al., 2008). The application of the integrative PSS approach to the design of smart lab product-service system solutions in a traditional manufacturing industry showed that it can support manufacturing companies' development of integrated solutions with a service perspective. Again, qualitative research was used to collect and analyze the data from the regular meetings with the design team throughout the process (Charmaz, 2014; Strauss & Corbin, 2015). These regular meetings contributed to refinement of the design models and improve the integrative PSS approach (see section 5 evaluation and Figure 14 for more details).

Having described the methodology, the next section describes the conceptual development of the integrative PSS approach and its application to the design of smart lab product-service system solutions (section 3 and 4).

3 The integrative PSS approach: designing product-service system solutions with a Service Design perspective

The integrative PSS approach addresses the challenge of supporting the manufacturing industry evolution toward servitization by enabling the design of new solutions that leverage the PSS product- and organizational network-oriented view with the interaction, human-centered, and experience design view of Service Design. Following a design thinking process, the integrative PSS approach iteratively follows the stages of exploration, creation, prototype and testing, and implementation (Johansson-Sköldberg et al., 2013). However, the final stage (usually called implementation) was relabeled planning implementation, as it concentrates on preparing the transition from product-service system concepts and prototypes to launch.

The integrative PSS approach brings together different contributions across the design stages, as depicted in Figure 2. PSS and Service Design already provide methods and models for designing new solutions. However, the literature review showed that Service Design focuses on the first stages of the design process and not so much on the latter

stages of the process. At the same time, current PSS design models focus on the exploration and planning implementation stages, providing less support for the creation and testing stages, as shown in the lower part of Figure 2.

The integrative PSS approach, therefore, stems from current models of PSS and Service Design to create new ones (middle row of Figure 2). As existing models were not previously integrated, the new visualizations support the design of product-service system solutions in a more consistent manner throughout the design process. At the exploration stage, the Extended Customer Experience Modeling details the customer experience and emphasizes physical contextual elements. At the creation stage, the PSS Constellation, Navigation and Value Matrix support the co-creation of product-service system solutions at multiple levels, in terms of envisioned experience, potential supporting product and service resources, and back-end processes. At the prototype and testing stage, physical product prototypes are combined with storyboards, providing a more complete view of the physical product and service components that enable a smooth customer experience. Finally, the integrative PSS approach examines the supporting organizational network components through the PSS Organizational Network Map to facilitate the implementation of the solutions in context. The integrative PSS approach process and new models are described in detail below.

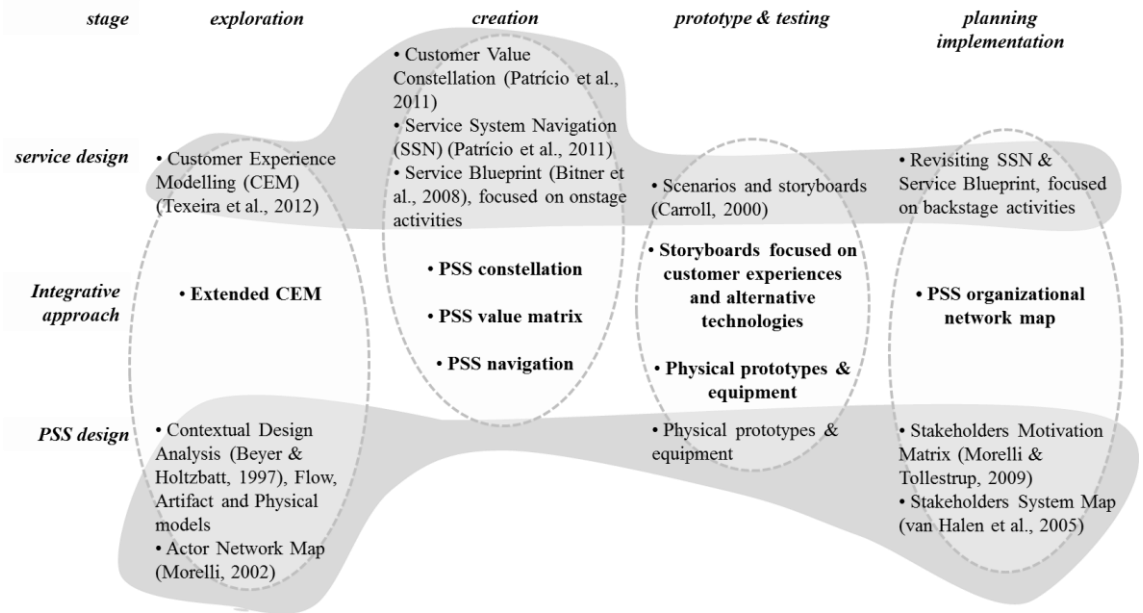

Figure 2. Design models in Service Design, PSS, and integrative PSS approach

3.1. Exploration

In the integrative PSS approach, the exploration process begins with an analysis of the customer experience, taking into consideration the physical product and service components. To this end, it combines the Actor Network Map from PSS, with the Flow, Artifact and Physical Models of the Contextual Design Analysis. While the first model offers a systemic perspective of the design context, the latter models provide a more local view, identifying breakpoints between actors' flow of information and actions, as well as existing problems with product and service usage. The integrative PSS approach also combines the Physical and Artifact models with the customer experience perspective from Customer Experience Modeling (CEM) and evolves this to create the extended CEM. The extended CEM operationalizes the experience within a design space by emphasizing the physical components of the model, depicting how customer experiences are connected to particular spaces and equipment in context. Therefore, the integrative PSS approach enables a detailed view of the customer experience and its contextual elements, highlighting the physical elements to identify local (equipment- and space-oriented) and systemic (service system) problems and opportunities.

3.2. Creation

To support the co-creation of new product-service system solutions, the integrative PSS approach involves considering the value co-creation processes within larger service networks to design the solution at multiple levels. As such, the integrative PSS approach evolves the Customer Value Constellation (Patrício et al., 2011), which maps the services in the customer network to the PSS Constellation by detailing the goods and physical evidence that form the service concept. The PSS Constellation model enriches the representation of the service concept by outlining potential supporting physical resources and technologies that enable value co-creation with customers. At the conceptual level, the PSS Value Matrix is built parallel to the PSS Constellation. The PSS Value Matrix depicts how customer activities can be supported by different product-service system resources and outlines key characteristics of equipment, technologies, and other resources to offer a compelling value proposition to customers. The combined use of the PSS Constellation and PSS Value Matrix at the conceptual level supports the definition of integrated value propositions within the manufacturing context and facilitates the transition to the prototyping and testing stage.

After the design of the product-service system concept, PSS Navigation supports the design of the customer experience, which is an evolution of the Service System Navigation. PSS Navigation combines the rich visual information of storyboards displaying the product-service system experience, with information about the orchestration of multiple resources required for both front stage and backstage processes to enable value co-creation among stakeholders. With this multilevel perspective, the integrative PSS approach supports the definition of the integrated solution, considering both customer experience and actors' resources.

3.3 Prototype and testing

The PSS literature supports the development of (living) labs for testing, learning, and improving product-service system solutions (Hillgren, Seravalli, & Anders, 2011; Liedtke, Baedeker, Hasselkuß, Rohn, & Grinewitschus, 2015). Although it is effective for learning about the multiple dimensions that affect the customer experience (Ceschin, 2014), this strategy can be very expensive for manufacturers starting their journey toward service. As such, the PSS integrative approach combines storyboards and physical prototypes to enable a low cost yet potentially effective approach to prototype integrated solutions. On the one hand, storyboards provide effective visual tools that represent the customer experience with the interactions that occur between different actors, service interfaces, and equipment. On the other hand, the physical prototype allows for testing integrated solutions with customers, and is included within the testing stage with the experience perspective provided by the storyboards. Together, they contribute to a customer-centric view and enable rich customer feedback on the physical product and service components of the solution.

3.4 Planning implementation

From an S-D logic perspective, the distinction between goods and services becomes blurred (Lusch & Vargo, 2014). However, product ownership has important implications for how Service Design is implemented within the organization and for the customer experience as well. Thus, designing within a integrative PSS approach requires looking at the backbone of PSS design - that is, product ownership (Tukker, 2004; Valencia et al., 2015). Product ownership entails deciding whether to transfer physical products to customers or to make them available strictly for use (e.g., leasing/renting). To support this task, the integrative PSS approach simplifies the

Stakeholder System Map into the Organizational Network Map. The latter uses previous design models to represent who and how organizational networks interact and co-create value. In particular, it represents key supporting product-service system resources, value co-creating interactions among organizational network actors, and customer networks. The Organizational Network map complements the PSS Navigation model to support the analysis of the impact of ownership design decisions on the customer experience and the organizational network components.

Finally, because product-service system solutions imply important changes in customer practices and behaviors (Bhamra, Walters, & Moultrie, 2017), the supporting back-end processes and supporting networks are reorganized to enable the occurrence of the desired customer experience. The company plans actions to continuously develop and refine solutions according to the feedback provided from customers, and incorporates the changes within the internal organizational processes. This is important for stimulating service innovation and assessing the need to continuously enlarge networks. Finally, the Stakeholder Motivation Matrix (Morelli & Tollestrup, 2009) can support the adjustment and negotiation of the expectations, motivations, and roles of the multiple actors involved in the project.

4 Application of the integrative PSS approach to design smart lab solutions

Following the design research approach outlined in section 2, the integrative PSS approach was applied in the context of a manufacturing firm. This application involved designing new smart lab product-service system solutions in a mid-sized Portuguese company that develops and produces specialized laboratory equipment. This application provided a testbed for evolving the integrative PSS approach.

The research team guided the design activities, applying the integrative PSS approach and models along the four main stages of the design process, as shown in Figure 3. The company assigned a multidisciplinary team to the smart lab project, comprising five people with experience in design, engineering, and management, led by the CEO. Customers (labs from the industrial, educational, and healthcare sectors), research partners (biomechanical and electromechanical researchers), and industrial partners (small equipment providers, security lockers, among others) were also involved at different stages of the research project. The fieldwork lasted for six months and

provided a rich setting to understand the usefulness of the integrative PSS approach and support the company's servitization process.

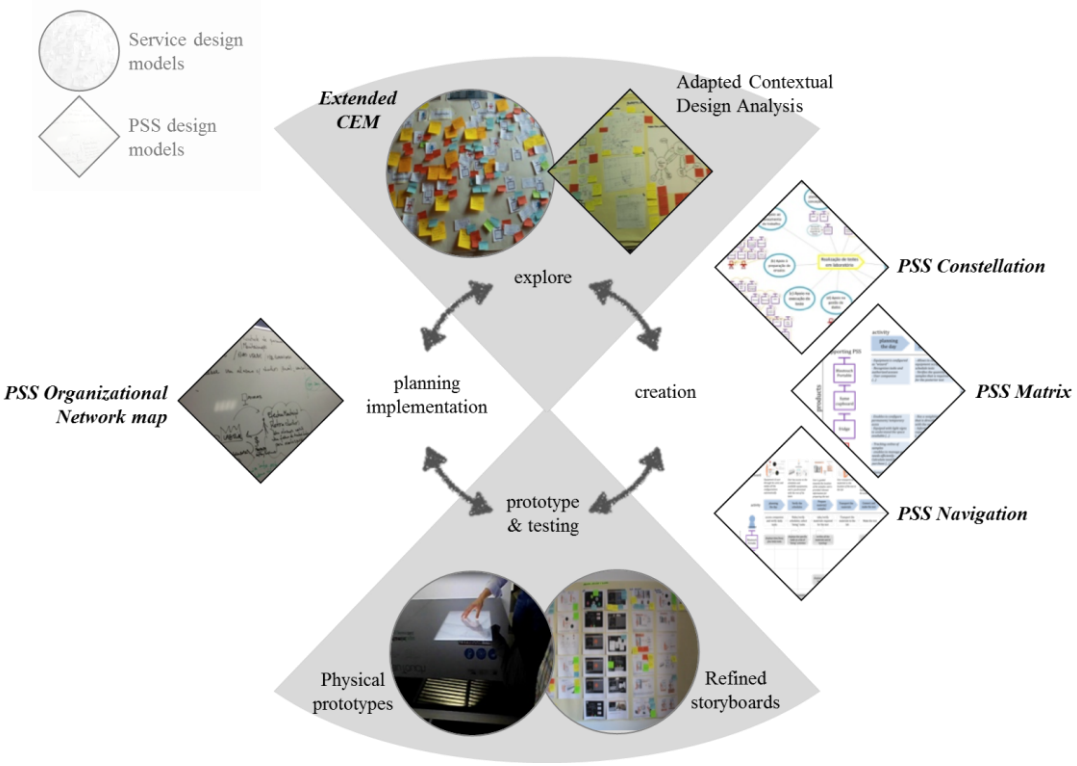

Figure 3. Integrative PSS approach design process and models used

The application of the integrative PSS approach included multiple stages as detailed in Table 1, following a design thinking process of exploration, creation, testing, and implementation. Qualitative research was used in the exploration and testing stages to develop an in-depth understanding of customer experience, develop and refine the product-service system solutions, and co-create the design models (Figure 3). The next sections detail the process and results obtained in the application of the integrative PSS approach.

Table 1. Stages of the integrative PSS approach application

	Activities	Objectives	Sample design	Outcomes/Models
Exploration	One internal workshop	Identify actors involved in the system	15 collaborators from the company including industrial designers, mechanical and electromechanical engineers, bioengineers, and managers	Actor Network Map

	Three laboratory visits	Understand physical spaces and customer experience in context	3 pharmaceutical laboratories, interviews with 3 lab managers, 1 logistic manager, and 6 lab users	Artifact, Flow, space Models
	Three exploration and co-design sessions	Understand customer experience	Participants included: 10 company collaborators and 7 partners (which participated in the three days sessions), and 23 lab users and managers from industrial, education and health sectors	Extended CEM
		Co-create new concepts		PSS Constellation
Creation	Two internal co-design sessions	Prioritize ideas according to relevance for key stakeholders and companies resources; co-create new integrated solutions	Company design team and CEO	PSS Constellation, Value Matrix and Navigation; Initial Storyboards
Testing	One testing session	Test the product-service system solutions with potential customers	5 potential customers from the integrated solutions and design team	Refined Storyboards; Physical Prototypes
Planning implementation	One internal PSS workshop	Revisit required PSS organizational networks and value co-creation processes; build action plan for implementation of solutions	11 collaborators from the company with different backgrounds	Refined PSS Navigation; PSS Organizational Network Map

4.1 Exploration: understanding the laboratory customer experience

A qualitative study was conducted to develop an in-depth understanding of customer experience (Charmaz, 2014; Strauss & Corbin, 2015). Following qualitative guidelines, the sample design in the exploration stage was defined according to participants' relevance to gain an in-depth understanding of the experience of the different stakeholders. As such, the sample comprised lab users, managers, suppliers, and

members of the company's development team, with diverse backgrounds and experience.

To enable a rich understanding of the stakeholder experience, multiple data collection methods were used. For example, laboratory visits complemented the group interviews in the exploration sessions. These visits were used to further develop themes related to physical space and flow of interaction, as well as to identify problems that would only be perceived while in context (e.g., seeking materials and/or samples).
Data collection involved semi-structured interviews (individual and group) and observations with field notes. Group interviews were recorded during both lab visits and workshop sessions. Physical models were also used to support the discussion during the exploratory sessions (Figure 4 and Figure 5). These data were qualitatively analyzed (Charmaz, 2014) to identify emergent categories, such as stakeholders' role, experience requirements, product materials and services, as well as physical contextual elements. These results supported the development of the different models.

The exploration stage started with an analysis of the context of laboratory usage and problem framing, through an internal workshop and semi-structured interviews with the company's development team. This enabled a basic understanding of the company's business model, stakeholders, products, and desired areas for improvement and also supported the development of a preliminary Actor Network Map (Morelli, 2002). This collaborative effort helped the company develop a broader view of the service systems in play in the lab industry, encouraging detachment from their initial product-oriented perspective toward PSS innovation.

Then three full-day exploratory sessions were run with the most relevant stakeholders. Data collected through these exploratory sessions were analyzed following a qualitative approach (Charmaz, 2014) to identify and develop the categories mentioned above (i.e., stakeholder role, experience requirements, product materials and services, as well as physical contextual elements). These enabled the development of the Extended CEM model (Figure 4), identifying 12 key customer activities. The activities emphasized by customers as needing improvements were executing tests, data management, planning, and preparation. This model was important for aligning customers' and company's

perspective on what constitutes relevant value-in-use. It also provided a broad view of the customer experience, emphasizing the physical artifacts within lab spaces.

Figure 4. Extended CEM

The analysis of the Actor Network Map and Extended CEM indicated that the company and the research team should focus on the pharmaceutical industry, which was considered more interesting for PSS innovation due to its complexity. To complement the study of customer experience and enrich the data collection, in-situ inquiry in labs was undertaken. After each visit, the research team systematized the findings into an adapted Contextual Design Analysis (Figure 5) with the Artifact, Physical space and Flow Models. It included resources in-situ, physical spaces, actions, and interaction flow between actors.

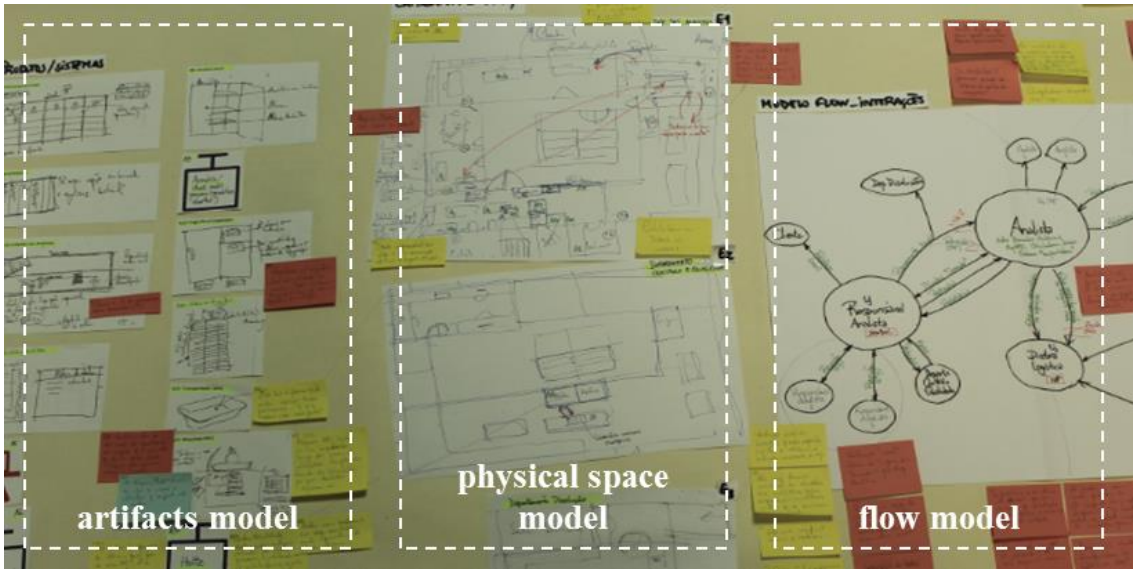

Figure 5. Adapted Contextual Design Analysis: artifact, physical space, and flow models

The analysis of the data collected during the lab visits revealed new categories of problems only observed in situ. For example, it showed that users needed to access multiple types of information before, during, and after the tests in the lab, while preventing the risk of contamination. It also outlined the systemic problems with regard to shared materials and samples, and for sharing equipment, depicted in the Physical Space model. Finally, both users and managers complained about the lack of tracking systems inside the lab, which resulted in materials missing and significant time loss. These problems were outlined in the Flow, Artifact and Physical Space models, which complemented the extended CEM. These results and respective models contributed to (1) the development of a more local view of the connections between the physical product and service components; (2) the connection of actors to physical spaces and artifacts; and (3) understanding how current organizational network components impacted the customer experience, such as actors' roles and information exchange (Flow model). The qualitative analysis undertaken supported the creation of the integrative PSS approach models in the exploration stage. Together, these models provided an in-depth understanding of how physical space, equipment, and network interactions were contributing deeply to both local and systemic problems.

4.2 Ideation: Creating new smart lab product-service system solutions

The results of the exploration stage were used to support the co-creation of new product-service system concepts, taking into account the customer experience from both the local and systemic perspectives.

4.2.1. Designing product-service system concepts

The co-creative concept generation workshops facilitated brainstorming new product-service system concepts to support laboratory activities, using the PSS Constellation (Figure 6 and Figure 7) and the PSS Value Matrix (Figure 8). The PSS Constellation connected customer activities to potential resources in terms of both physical products and service, in a systemic way. This was important for mapping possible solutions and discussing different alternatives. Moreover, the PSS Value Matrix depicted the key characteristics and requirements of the physical evidence of product-service system solution.

The development of the PSS Constellation enabled participants to brainstorm and discuss potential equipment and technologies (among other things) to support customer activities. Using both models in parallel was indispensable for connecting service experiences with product characteristics.

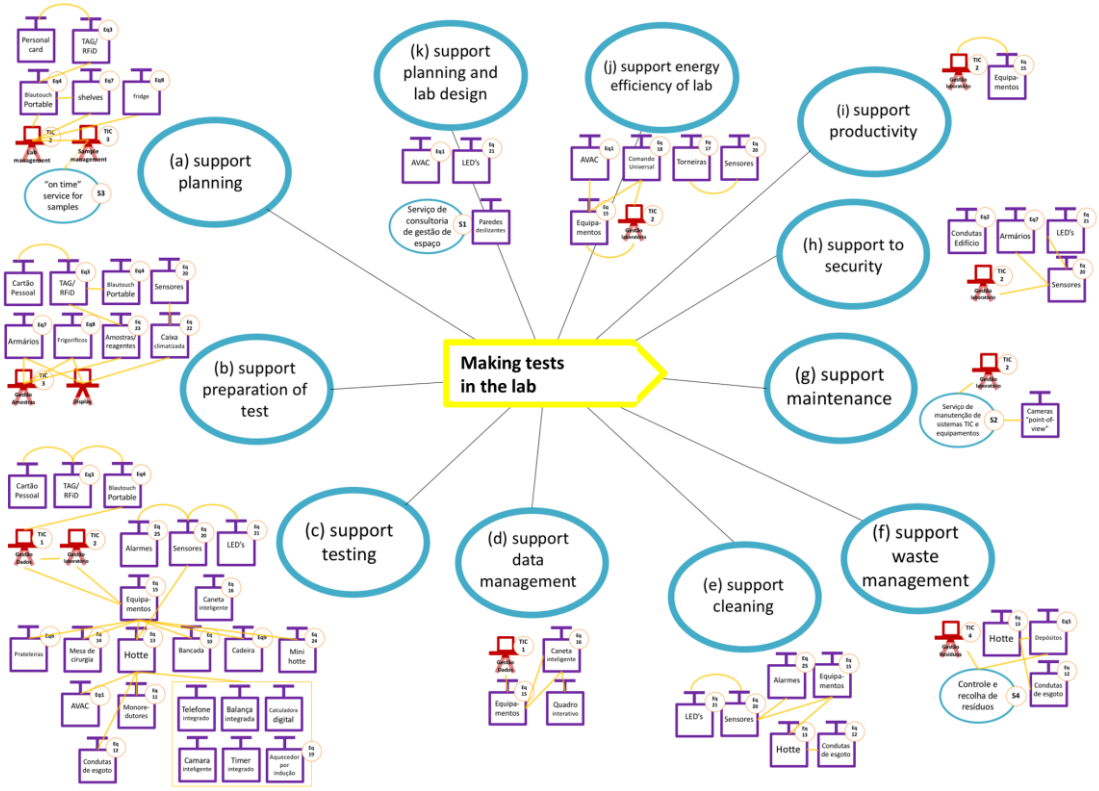

Figure 6. PSS Constellation

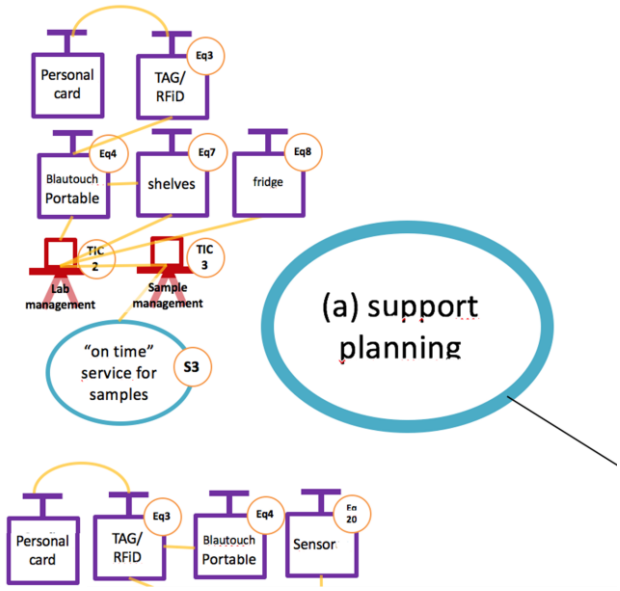

Figure 7. Detailed view of the PSS Constellation

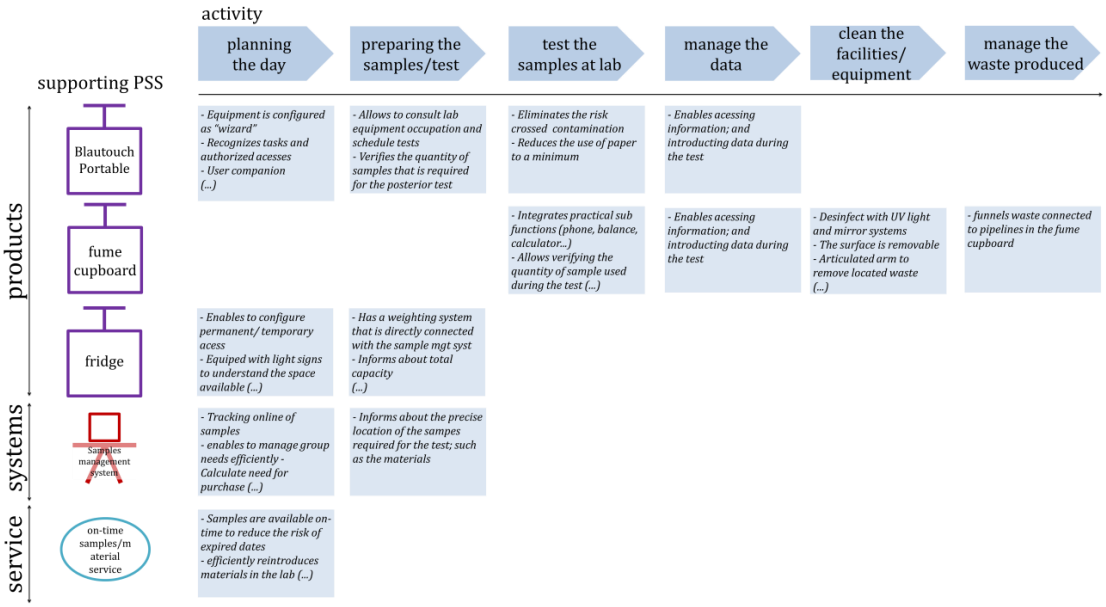

Figure 8. PSS Value Matrix

The different combinations of product-service system resources focused on solving either systemic or local problems. An "interactive dashboard" to support users planning activities was considered a solution for a local problem, whereas a "shared equipment management service system" solution was used to address problems occurring in different activities in a more integrated and systemic way, involving multiple stakeholders.

The combination of product-service system resources led to scenarios (Carroll, 2000) and concepts that were prioritized and selected according to their potential for value co-creation. Preliminary storyboards were developed iteratively, depicting the customer experience with the integrated solution, alternative technologies and services, as well as information exchange between customers and stakeholders (Figure 9).

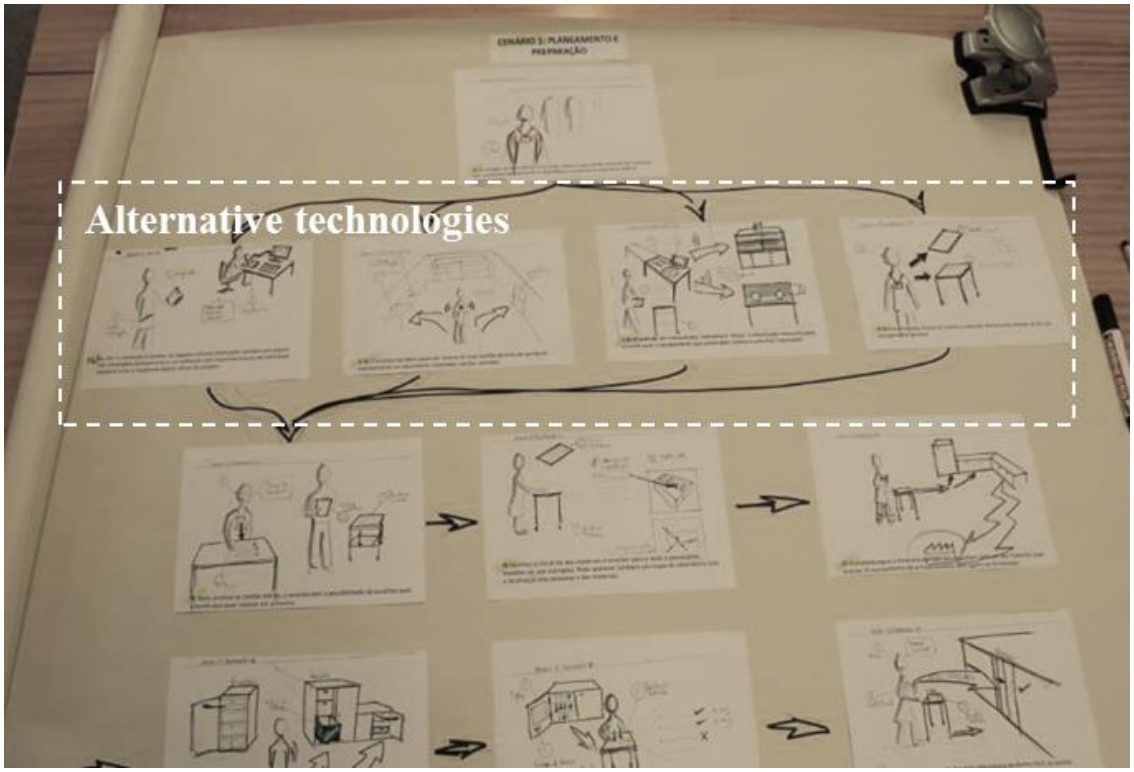

Figure 9. Preliminary storyboard with suggestion of alternative PSS resources

This process resulted in the co-creation of five novel product-service system concepts that were iteratively refined. Some of these concepts were more service-oriented, such as the smart storage product-service system solution. Other concepts were more product-oriented, such as the smart fume cupboard and smart countertop solutions. Together, these different concepts formed a more systemic concept of an integrated product-service system smart lab, as a more holistic and complete solution to support the laboratory user experience involving the intervention of multiple stakeholders.

4.2.2. Designing the solution service system

To detail the orchestration of product-service system solutions, the PSS Navigation model depicted the customer experience through storyboards while also orchestrating the multiple resources required to enable the occurrence of the customer experience. The model in Figure 10 depicts how the customer navigates the multiple product and service interfaces. It also depicts the flow of product-service system actions between smart equipment and systems of actors and provides a high-level view of the system operation for value co-creation.

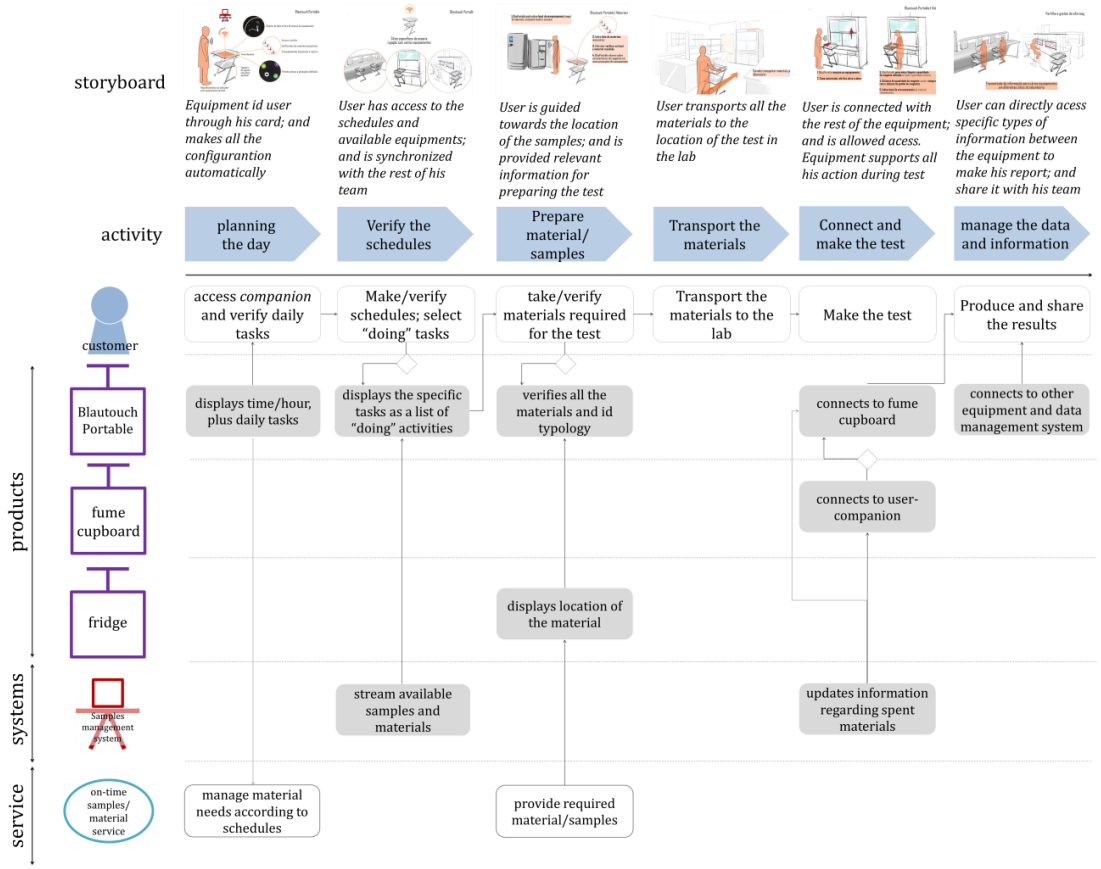

Figure 10. PSS Navigation for the smart companion solution

For the smart companion solution, the PSS Navigation depicted in Figure 10 illustrates how users log in to the companion and access their personalized information to support daily tasks. They are guided throughout the lab according to their daily tasks. Moreover, reports are created and shared more efficiently because the different equipment and systems in the lab are connected.

Overall, the integrative PSS approach and models opened up new possibilities for product-service system innovation that supported the co-creation of more complete and systemic lab solutions. The participation of multiple stakeholders in the initial stages enabled fruitful discussions between stakeholders regarding how integrated solutions enhanced the customer experience, and was paramount in supporting the design decisions during the process.

4.3 Prototyping and testing smart lab product-service systems solutions

On the basis of the results obtained in the creation stage, the prototype and testing stage combined the physical realization of the product-service system solution with

storyboards illustrating the flow and context of the customer experience (Figure 11 and Figure 12). This provided customers with a more complete perspective of the intended PSS experience as well as the interactions between different actors, service interfaces, and equipment.

A testing workshop was organized to discuss, test, and improve the product-service system solutions. The sample comprised five potential customers (Table 1). Observation including field notes and audio-recordings were undertaken during the session. The data collected were analyzed and used to improve the solutions and prototypes.

A qualitative analysis indicated that lab users were open to learning new competencies as long as the solution's benefits would result in enhanced work productivity. However, they first required modular offerings (e.g., smart companion solution) instead of all-encompassing solutions (integrated smart lab solution) to better support the progressive learning of new competencies and adaptation of working practices.

Figure 11. Discussion and evaluation of the product-service system solutions

Figure 12. Test and discussion of the physical products of the integrated product-service system solutions

Customer feedback was important for refining and combining product-service system solutions. Thus, it was used to support strategic decisions in terms of progressive learning. The integrative PSS approach enabled the company to develop a more complete perspective of the customer experience. During this process, it was essential to abandon the more traditional product-testing perspective, focused on improving technical features, and shift toward a more holistic and experience-centered perspective.

The application of the integrative PSS approach at this stage was important for understanding the intended customer experience and the positioning of the company's offering within the customer value constellation, as opposed to focusing on products per se. In addition, the company was able to better understand how the connection between product and service interfaces would impact the customer experience.

4.4 Planning the implementation of product-service system solutions

After the prototype and testing stage, the integrative PSS approach involved planning the required organizational networks. To this end, an internal session was organized with the development team to integrate the customer feedback and examine and orchestrate the potential organizational networks required to operationalize the solutions. While revising the PSS Navigation, the PSS Organizational Network Map was constructed (Figure 13). This was important because it allowed for analyzing the value co-creative processes from the company's perspective while keeping the customer experience in mind.

The PSS Organizational Map was useful for defining, in a dynamic way, the outcomes and possible service processes of each of the stakeholders involved in the product-service system solution. Installing a fully integrated smart-lab would be expensive for customers, and imply significant changes in their practices. To facilitate gradual learning, as outlined in the testing stage, two strategies were used: first, to use the intelligent companion as an enabler for transformation of customer practices; and second, to assess which product components of more integrated solutions could be rented in the long term, thus building longer relationships with customers. This would be useful to refine the service component of the solution before reaching full implementation. In this application, the PSS Organizational Map was important not only for identifying missing partners but also for outlining a plan of short- and long-term actions, exploring also rental models for the equipment.

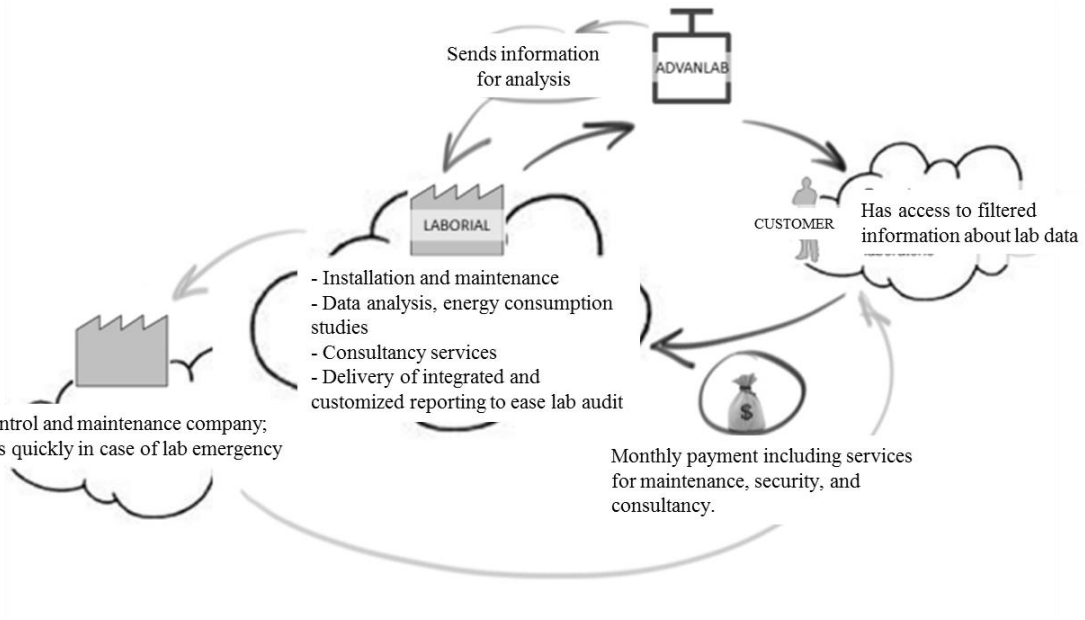

Figure 13. Example of PSS Organizational network map

Finally, although the research project did not reach full implementation within the prescribed time frame, the application case showed that the new integrative PSS approach supported the design of new product-service solutions and enabled the company to shift its vision from a product-oriented design approach to a more service-oriented design approach. The design models facilitated discussion between multiple stakeholders and were helpful in connecting the customer experience perspective of

Service Design to the organizational networks and physical components of PSS, which are the backbone of the manufacturing industry. Overall, the application evinced that the integrative PSS approach can bring together the PSS and Service Design perspectives to allow for envisioning more holistic solutions focused on enabling value co-creation for customers, while supporting the operationalization of those solutions in later stages of the project to prepare for implementation.

5 Evaluation of the integrative PSS approach

Following design research criteria and Design Science Research guidelines, the present study was intended to evaluate the usefulness of an integrative PSS approach and its models. First, the approach was tested through a real-life application in a manufacturing context. This application, described in section 4 showed that the integrative PSS approach enabled the company to generate a portfolio of five different product-service solutions that together presented a more holistic value proposition to customers. The testing sessions with the different customers also yielded positive feedback regarding the solutions developed using this approach. Some solutions were partially implemented during the research project and others were developed later on.

The integrative PSS approach also facilitated progressive learning in the company, supporting the transition to a solution-oriented mindset. Feedback on the integrative PSS approach process and models was collected at different points throughout the application (Figure 14): (1) after data collection and analysis, to assess the usefulness of the integrative PSS models to systematize the customer experience; (2) after the internal PSS design workshops to define the product-service system concepts; (3) in weekly meetings which were documented through review meeting reports; and (4) in an internal workshop after the user testing session. The feedback was incorporated in the models and refined the approach (Sein et al., 2011). In particular, the internal workshops and weekly meetings contributed to change the structure of the models: the PSS Value Matrix, which initially comprised a list of product and service requirements, was restructured according to customer activities.

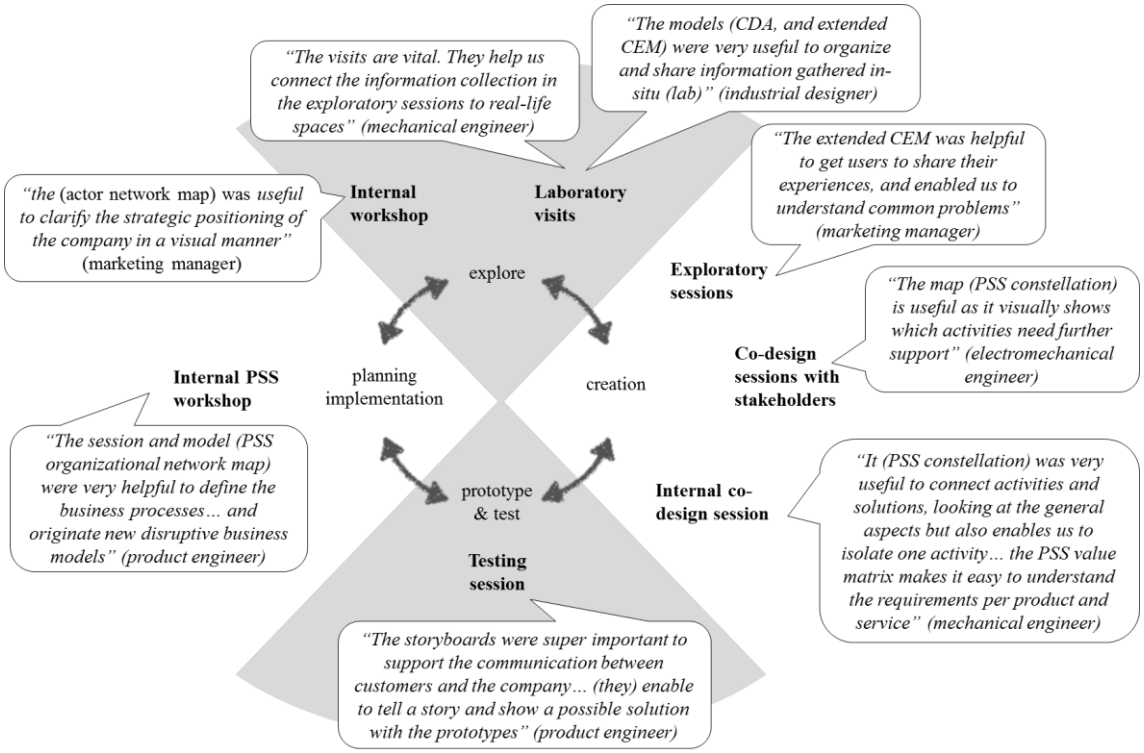

Figure 14. Qualitative data obtained throughout the application of the integrative PSS approach and models

At the end of the application process, a final internal workshop was conducted to evaluate the usefulness of the process and relevance of the overall integrative PSS approach. Again, qualitative research tenets (Charmaz, 2014; Strauss & Corbin, 2015) were used to ensure that the workshop covered all relevant participants (company CEO, all members of the development team from other related departments). The data collected were qualitatively analyzed to identify the main contributions and limitations of the different models and the process as a whole. Overall, the participants considered that the PSS approach enabled (1) a more customer-centric approach with a focus on solutions within the customer value constellation and in the overall system of solutions in the network; (2) a shift from a product-centric to a holistic systems view, both in terms of the organizational network and the customer network; and (3) the provision of more structured support within the models for moving along the different phases, supporting analysis and discussion among different stakeholders, including customers, and allowing the team to make more informed design decisions. However, the limitations that were mentioned included the time and effort needed to involve the different stakeholders along the process and the challenge of changing the mindset from

a product-oriented to a solution-oriented approach focused on value co-creation with customers.

Finally, the research contribution of the integrative PSS approach was assessed according to the design research criteria (Forlizzi et al., 2008). First, with respect to the process, the design used in the integrative PSS approach was thoroughly detailed to enable further replication and improvement in future projects. Second, as regards invention, the description of the integrative PSS approach in light of previous PSS and Service Design literature showed how it integrates and evolves previous methods and models for a systemic design of product-service system solutions, integrating the customer experience and the organizational network perspectives. Third, with regard to the relevance of this research, the application in a real-world context evinced how it can support the development of new product-service system solutions and help the company in its servitization process. Finally, regarding extensibility, the successful application of the integrative PSS approach to co-creating integrated solutions within a manufacturing context indicated that it can also be used in other manufacturing contexts.

6 Contributions

This paper presents an integrative PSS approach to support the design of new product-service system solutions for value co-creation within manufacturing industry, bringing together PSS and Service Design through the lens of S-D logic. Overlaps and complementarities of the three fields were examined and integrated to devise a systemic approach. The definition of the value proposition is considered a significant challenge in both PSS and Service Design (Baines, Bigdeli, & Bustinza, 2017; Goldstein, Johnston, Duffy, & Rao, 2002; Raddats, Baines, Burton, Story, & Zolkiewski, 2016). The new integrative PSS approach combines the customer experience and value co-creation perspective of Service Design, with the organizational network perspective of PSS to support the design of systemic product-service system solutions.

The study built on existing design models, integrating and evolving them to bring the integrative PSS approach to design practice through new visualizations. In the exploration stage with the extended CEM, this approach emphasized not only the interactions between actors and service interfaces but also physical spaces and artifacts. In the creation stage, it evolved previous models to support the design of integrated

solutions from a multilevel perspective, emphasizing the physical components of service and organizational network components through the PSS constellation and PSS navigation. Additionally, the PSS value matrix provided a smooth transition from the creation stage to the prototyping and testing stage by connecting customer activities with product-service system resources as well as physical product and service characteristics. In the prototype and testing stage, the physical prototypes were linked to storyboards, combining service and product components and enhancing communication between stakeholders and customers regarding product-service system usage. Finally, in the planning implementation stage, the PSS Organizational Network Map provided a high-level representation of key value co-creation processes and organizational networks.

Overall, the integrative PSS approach and models increase awareness about the supporting components necessary to enable a real customer experience with the product-service system, while supporting the transition from a product-centric to a future solution-oriented business model. The integrative PSS approach also contributes to advancing the design practice. This study provided evidence that the application can be used in complex manufacturing contexts to design new integrated product-service solutions with a stronger service perspective. It also enables manufacturers to solve real-life problems while leveraging contributions from PSS and Service Design to foster PSS innovation, facilitating a change in mindset to adopt more service-oriented and value co-creation design approaches.

7 Conclusions and future research

PSS design research is facing increasing challenges, particularly in regard to designing systemic, integrated product-service solutions and infusing service in the manufacturing industry. This research addressed these challenges with the development of a new integrative PSS approach and models that support manufacturing companies designing holistic product-service system solutions with a Service Design perspective. The results of the case study application show that the integrative PSS approach was able to support a company in its transition from a product-oriented mindset to a service mindset, allowing the company to create new product-service system value propositions with customers and expand the company design portfolio.

Nevertheless, this research also had some limitations, which indicate directions for future research. Although the case company offered a rich manufacturing context, the integrative PSS approach was applied only to one design case. A single case cannot determine whether this approach is more effective than other possible approaches. Further research should extend its application to different manufacturing settings to enhance its robustness. Infusing a service perspective in manufacturing companies is important, but service providers can also benefit from better incorporation of physical evidence and organizational network components into their service design process. Therefore, future research may explore the application of the integrative PSS approach to service-oriented contexts to enhance its extensibility.

The application of the integrative PSS approach to the development of new smart lab solutions required significant resources throughout the different stages of the design process. However, other PSS design projects may not afford such significant efforts. It would be useful to study potential adaptations of the integrative PSS approach to support design projects with shorter development periods and fewer human resources. Moreover, the application did not include production and launch. Therefore, it would be necessary to explore how it can be extended to further design stages.

Finally, this study constitutes a significant step toward advancing design research at the intersection of PSS and Service Design and represents a broader application of an integrative PSS approach in the organizational context.

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Paper 3: Expanding the boundaries of Product Design and Service Design through PSS[3]

Abstract

The design of more complete solutions that integrate product and service components has become increasingly important for companies to add value to their offerings. In this context, the majority of Product Service System (PSS) research has focused on supporting the transition from goods to service-oriented businesses. However, recent work indicates that an expansion strategy can be preferred to full-transition toward PSS. In this context, it is important to understand how product design and service design approaches can be extended through partial infusion of PSS.

This article presents a multiple case study of with 5 projects using a product design approach (PD-projects), and 5 projects using a service design approach (SD-projects). It explores how PSS approaches can enrich product design and service design. Qualitative research comprehended components of ethnographic research, involving in-loco observations, document analysis, physical artefacts and semi-structured interviews.

The results of data analysis indicated four main differences between product design and service design approaches: (1) stakeholders' role; (2) design approach versus design object; (3) design space versus design context; and (4) materialization of solutions. The study also showed that the introduction of PSS had a different impact in PD- and SD-projects. In PD-projects, PSS approaches fostered problem reframing by considering a broader set of stakeholders and systems, expanding the scope of design solutions. In SD-projects, PSS was more useful in later stages of the design process by bringing service concepts closer to the implementation stage, emphasizing physical evidence and products in service.

This study contributes to advance product design and service design research and practice, depicting key differences between the approaches both theoretically and empirically. It also shows how PSS design can be useful to enrich product design and service design through their different stages to co-create more integrated solutions.

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Keywords - Product-Service Systems, Product Design, Service Design, Service-Dominant Logic, Multiple Case Study, Servitization

1. Introduction

Globalization and the rapid evolution of technology have led design to a transition movement, more focused on human systems, services, communities and organizations, rather than physical products per se (Buchanan, 2001; Manzini, 2006; Sangiorgi, 2011; Yee et al., 2014). Within a context characterized by dematerialized markets (Normann, 2001), manufacturers and service providers alike attempt to create more complete solutions for/with their customers (Morelli, 2009a). On the one hand, realizing the limits of offering tangible products, manufacturing companies increasingly infuse service in their offerings (Baines et al., 2007; Mont, 2002). On the other hand, service companies also pay additional attention to the multiple physical elements within service, which are key to enable smooth customer experiences (Berry, Shankar, Parish, Cadwallader, & Dotzel, 2006; Lo, 2011).

The combination of product and service components into integrated value propositions that deliver value-in-use to customers is usually referred to as Product-Service System (PSS) (Baines et al., 2007). The first approaches to design PSS solutions were more focused on improving efficiency and performance of technical systems (Cavalieri & Pezzotta, 2012; Vasantha, Roy, Lelah, & Brissaud, 2012) and represent an effort to shift towards a more functional economy (Mont, 2002; Tukker, 2015). However PSS solutions resulting from this perspective can be more difficult to infuse in markets due to customers non-acceptance (Ceschin, 2013; Rexfelt & af Ornäs, 2009; Vezzoli, Ceschin, Diehl, & Kohtala, 2015).

To address this issue, contributions from service design have emphasized the social component of PSS (Morelli, 2002), exploring customer experiences and value co-creation processes in service (Costa, Patrício, & Morelli, 2016; Costa, Patrício, Morelli, & Magee, 2017). Integrating PSS with service design has enabled the co-creation of more complete solutions. However, this perspective can be difficult to be fully embedded in companies. Certain design practices can be difficult to change (Junginger, 2014), especially when full-transitions are required. Additionally, full-transition towards PSS may not always bring additional value (Kowalkowski, Gebauer, Kamp, & Parry,

2017; Tukker, 2015; Tukker & Tischner, 2006). Current design approaches such as product design and service design, still play an important role in companies. As such, it is important to better understand these approaches, in theory and in practice, to enrich them and facilitate the co-creation of more integrated solutions (Costa et al., 2017).

On the one hand, product design is deeply rooted in manufacturing industries (Junginger, 2014; Junginger & Sangiorgi, 2009) and has evolved considerably through the years, going from exploration of form and function, materials and manufacturing, to more complex issues such as emotions and experience (Desmet & Hekkert, 2007; Yoon, Pohlmeyer, & Desmet, 2016). Product design has thoroughly explored multiple dimensions of physical products to enhance user-product experience (Desmet & Hekkert, 2007; Yoon et al., 2016) while assuring that products are functional, reliable and can be manufactured (Kim & Lee, 2016; Ulrich, Eppinger, & Goyal, 2011).
On the other hand, service design has emerged as a holistic and co-creative approach to design new service solutions (Meroni & Sangiorgi, 2011; Wetter-Edman, Sangiorgi, Holmlid, Grönroos, & Mattelmäki, 2014). Service design analyses and orchestrates multiple socio-material components to co-create value, and has a special focus on the service interface and the customer experience (Clatworthy, 2011; Kimbell, 2011; Patrício & Fisk, 2013; Secomandi & Snelders, 2011). Both product design and service design are important design approaches that can be enriched with PSS approaches to design more complete solutions but further research is needed to understand how they can they be integrated.

To address these challenges, this study used case study research to extend the boundaries of product design and service design through partial infusion of PSS. First, through literature review, current product design and service design approaches were analysed and compared. Second, the study examined how PSS components can enrich product design and service design. Then, a multiple case study research was undertaken involving 5 design projects adopting product design approach (PD-projects) and 5 design projects adopting service design approaches (SD-projects). This study enabled an examination and comparison of the different approaches. By introducing PSS components in all cases, the study also explored the different impact of PSS in the two sets of cases. Results showed that PSS can be more useful in early stages of the design process in PD-projects, supporting problem re-framing and expanding the scope of

solutions. Moreover, PSS design can also useful in SD-projects as it facilitates and better prepares the transition to the implementation stage.

The paper is organized as follows: the following section examines previous literature on product design and service design approaches, identifying the gaps when moving towards designing more complete PSS solutions. The methodology section describes the multiple case study research design. Then, the results from within case and cross-case analyses are described in chapter four. Finally, the paper discusses the implications and contributions of study results to advance PSS research.

2. Product design, service design and Product-Service system design

Product design and service design are two important streams of design. Product design is deeply rooted in manufacturing companies (Junginger, 2014), while service design has been initially developed with a focus on service industries (Sangiorgi & Prendiville, 2017; Yu & Sangiorgi, 2017). These approaches share a design thinking process (Brown, 2008; Johansson-Sköldberg, Woodilla, & Çetinkaya, 2013), but each has its own key principles and characteristics. These approaches are embedded within companies' design processes (Junginger, 2014) and are very important to design new products and services. However, the global design arena, characterized by rapid evolution of markets and technology (Rymaszewska, Helo, & Gunasekaran, 2017), requires companies to create more complete solutions to remain relevant. In this context, these approaches provide only a partial view to design integrated solutions.

Product-Service system (PSS) design has evolved to address such issue. It integrates product, service and organizational network components into solutions that deliver value-in-use to customers (Baines et al., 2007; Mont, 2002). Recent research has bridged the gap between PSS research and service design research to clarify and model design processes in service innovation (Costa et al., 2017). From this perspective PSS can contribute to expand product design and service design approaches, supporting the creation of more integrated solutions in both manufacturing and service companies. However, the implications of partial infusion of a PSS perspective in product design and service design approaches still require inquiry.

The following section analyzes and compares product design, service design and PSS design approaches, and identifies their overlaps and complementarities. Product design,

service design and PSS design share a design thinking approach (Johansson-Sköldberg et al., 2013). The design thinking stages are used as a guideline to facilitate the comparison between the approaches. The results and discussion and sections complement and compare the theoretical insights with the empirical analysis undertaken.

2.1. Product design

Product design integrates contributions from multiple disciplines to develop new products that enhance user experience (Kim & Lee, 2016), while assuring functionality, reliability, and manufacturability (Kim & Lee, 2016; Ulrich et al., 2011). Product design is especially attentive on the impact of products in users' lives (Bloch, 2011). This approach has been well developed in literature, but social and environmental pressures have been changing its practice (Papanek & Fuller, 1972; Sroufe, Curkovic, Montabon, & Melnyk, 2000). More integrated approaches aiming at waste reduction and changing user behaviour for sustainability are being developed and refined (Ceschin & Gaziulusoy, 2016). Likewise, experience and emotions related with physical products, have also been subject of increased attention (Bloch, 2011; Desmet & Hekkert, 2007; Yoon et al., 2016).

The product design approach usually follows a design thinking process (Brown, 2008) to create new solutions. Through multiple user-centred design techniques (e.g. observations or ethnographic-like methods, shadowing) (Gaver, Dunne, & Pacenti, 1999), designers and other experts (e.g. anthropologists) explore the context of use (Aranda-Jan, Jagtap, & Moultrie, 2016) to capture and better understand customer needs and emotions when interacting with products (Chitturi, 2009; Desmet & Hekkert, 2007). At this stage, users may be involved as consultants, or experts of their own experience (Sanders & Stappers, 2008). The exploratory process can result in a prioritized list of needs and design requirements which inspire the creation stage (Ulrich et al., 2011).

Problem definition and the construction of the solution co-evolve through iterative testing (Dorst & Cross, 2001; Kokotovich & Dorst, 2016). In product design in particular, multiple instruments such as sketching, models, low to high-quality prototypes are key instruments to materialize, share and evolve ideas in a rapid way (Ulrich et al., 2011). Different forms, textures and interfaces, material samples and

scales are developed and experimented upon to define the user-product interaction and experience (Lawson, 2006; Stolterman, 2008). It is not uncommon to design with a predefined target emotion (e.g. joy, wow-experience) (Yoon et al., 2016). The construction and validation of design requirements are key to inspire the creation stage. However, their construction should be supported by a more holistic understanding of the context to avoid systemic design failure (Aranda-Jan et al., 2016).

To bridge the product concept to its production, in the manufacturing plant, technical aspects are also explored. For example, the failure mode and effect analysis technique is important to understand possible components' failures (Stamatis, 2003). The design concept can be challenged through hypothetical scenarios, making the product solution more robust and likewise to be implemented. Desirability, feasibility and viability criteria (Fitzsimmons & Douglas, 2011) as well as market characteristics, production costs per product unit, sale simulations and cash flow analysis are also paramount for the later stages of the product design process (Ulrich et al., 2011).
This modus operandi has been well developed in product design education and practice. However, given the evolving complex settings within which it operates, and the important societal implications of its activity, it is crucial to expand product design towards a broader and more systemic perspective (Norman, 2010; Westerlund & Wetter-edman, 2017).

2.2. Service Design

Service design is an interdisciplinary field in expansion (Sangiorgi, 2009) that integrates holistic, human-centred, participatory and co-creative approaches to design new service solutions (Holmlid, 2009; Lin, Hughes, & Katica, 2011; Mager, 2009; Sangiorgi & Prendiville, 2017). Service design focuses on understanding, mapping and communicating customer experiences (Sangiorgi & Prendiville, 2014).

Whereas service design focuses on creating new service solutions, enabling value co-creation processes among multiple stakeholders (Wetter-Edman et al., 2014), product design focuses on creating new user-product interactions (van Rompay, Pruyn, & Tieke, 2009). As such, a fundamental difference between these approaches resides in the focus and the means through which positive customer experiences can be co-created.

Both product design and service design approaches follow a design thinking process (Brown, 2008; Johansson-Sköldberg et al., 2013). When comparing these approaches at exploration stage, both aim to understand customer needs and experience. However, service design literature takes a more holistic approach, exploring interactions between people, institutions, technological systems (Meroni & Sangiorgi, 2011; Patrício, Fisk, e Cunha, & Constantine, 2011), customer activities and experience requirements (Mickelsson, 2013; Teixeira et al., 2012). Product design usually explores the context within which products are included, and where user-product interaction occurs, and thus tends to have a more focused perspective (Ulrich et al., 2011).

At the creation stage, service design focuses on envisioning and orchestrating interactions between socio-material elements (Kimbell, 2011). Current service design methods support the orchestration between different service interfaces, multiple physical evidences and back-end processes (Bitner, Ostrom, & Morgan, 2008) and at multiple levels (service concept, service system and service encounter) (Patrício et al., 2011). From a service design perspective, design interfaces, processes and products supporting the interaction can be designed (Secomandi & Snelders, 2011), but the outcome and co-production processes cannot be fully predicted (Kimbell, 2011). This perspective is different from product design approach, which commonly targets specific emotions to develop solutions (Yoon et al., 2016).

At the prototype and testing stages, service design literature has made significant progress developing new ways of materializing service. Recent contributions of service research look at the activities within service design in the later stages of the design process (Yu & Sangiorgi, 2017), and integrates methods from different disciplines to support the visualization of the experience and back-end processes (e.g. mock-ups, low-fidelity prototypes, models) (Teixeira et al., 2017). However these methods do not yet detail the characteristics of physical products required to support the service experience.

Finally, service design literature reports that service solutions often fail to reach the implementation stage, counting few exceptions in public-sector organizations (Junginger, 2014). The front-stage and service experiences (Zomerdijk & Voss, 2010) are paramount in service and have been emphasized in literature. However, physical evidences and products should be more emphasized as they are key in service and

influence customers emotions and experience (Berry, Wall, & Carbone, 2006; Bitner et al., 2008; Blomkvist, Clatworthy, & Holmlid, 2016; Blomkvist, 2014; Lo, 2011). Moreover, physical products and organizational components, which are important to bring concepts closer to the implementation stage, need to be more developed in service design research (Morelli & Götzen, 2017; Yu & Sangiorgi, 2017).

Goods-Dominant logic and Service-Dominant Logic

The earliest perspectives of service design have evolved considerably in the last decades going from services as add-on to product offerings (Edvardsson, Gustafsson, & Roos, 2005), to a broader and co-creative logic of service (Vargo & Lusch, 2008). The former perspective is well exemplified by the IHIP model which stands for intangibility (services are not tangible), heterogeneity (services are not possible to reproduce as the people involved in its process are unique), inseparability (services are produced and consumed at the same moment) and perishability (services cannot be stored). The IHIP has been widely used to qualify services (Zeihaml, Parasuraman, & Berry, 1985) and is relevant when dealing with certain factors related with the design of services (e.g. time, interaction, ownership).

However, the modern economy led to revisions of this classification, since technology can overcome some of the limitations pointed by IHIP (Edvardsson et al., 2005). For example, through technology, services can be co-created at distance (e.g. web-based learning) and can be reproducible (e.g. software, programs etc.) (Moeller, 2010). IHIP therefore reflects a logic focused on goods to create value (i.e. goods-dominant logic, where product and service are interpreted as units-of-output of the production process). However, the latest interpretation of service - Service-Dominant Logic (S-D Logic) – makes this distinction between goods and service irrelevant, as it focuses on value co-creating processes (Lush & Vargo, 2014; Vargo & Lusch, 2016). Within S-D Logic, both product and service components are potential vessels for value co-creation, and value is only determined by the beneficiary of the solution (Lush & Vargo, 2014; Vargo & Lusch, 2016). Product/service providers, cannot fully control the outcome resulting from the interaction (Morelli & Götzen, 2016) since it is partially co-created by the customer (Grönroos, 2008, 2011)

The S-D Logic was integrated the service design approach, complementing service design practice with an overall framework to interpret existing service systems and act upon them (Wetter-Edman et al., 2014). However, S-D Logic is not so much emphasized in the product design approach. As seen in literature, product design allocates more effort in designing physical products to enhance customer experience and emotions (Desmet & Hekkert, 2007; Yoon et al., 2016), making a clearer distinction between the roles of providers and customers. From this perspective, providers are pre-producers of value which they embed in physical products along the value chain, and customers act more as passive receivers, consumers of value (Vargo & Lusch, 2016), and not so much as co-creators (Sanders & Stappers, 2008). As such, whereas service design has adopted the S-D Logic, Product design seems to adopt a Goods-Dominant logic. In order to expand and design more complete solutions, product design approach could benefit from adopting a broader perspective such as the S-D Logic.

2.3. Product-Service System design

The manufacturing industries are shifting from a product-centred to a more comprehensive solution-oriented perspective by infusing service in their offerings (Baines, Lightfoot, Benedettini, & Kay, 2009). PSS design has been supporting this transition by developing new methods and tools to create more integrated solutions (Baines, Bigdeli, & Bustinza, 2017; Tukker, 2015). Given recent contributions in PSS design research, this approach could potentially contribute to expand product design and service design approaches.

PSS design provides support to combine multiple product, service as well as organizational network components into new solutions that deliver value-in-use to customers (Baines, Lightfoot, Benedettini, & Kay, 2009). In PSS design, both product and service components are important and jointly influence the customer experience with the offering (Valencia, Mugge, Schoorman, & Schifferstein, 2015). PSS design has fairly evolved, going from the development of approaches focused on performance and efficiency of technical systems (Aurich, Fuchs, & Wagenknecht, 2006a; Maxwell & van der Vorst, 2003) to approaches focused on social components of PSS and value co-creation (Costa et al., 2017). Given the challenge of customer acceptance of PSS solutions (Rexfelt & af Ornäs, 2009; Stacey & Tether, 2014) new methods and tools were developed to investigate customer activities and behaviors, analyzing

technological potential (Morelli, 2003), foreseeing scenarios of use (Valencia Cardona, Mugge, Schoormans, & Schifferstein, 2014), creating new opportunities to generate value (Morelli, 2009b), and developing network-oriented management techniques (Isaksson & Larsson, 2009; Morelli & Tollestrup, 2009).

Recent studies in PSS design have integrated the PSS organizational-network oriented perspective with the human-centred and co-creative approach of service design, bridging these two design perspectives into a more integrated approach to design for value co-creation (Costa et al., 2017). Key characteristics can be outlined throughout the different stages of the design process. At the exploration stage, PSS integrated design approach emphasizes a multiple level analysis of the problem space, where customer experience, physical contextual elements, physical space, and organizational networks, are examined from multiple points-of-view. At the creation stage, the focus is on value co-creation processes in which both product and service components co-evolve in parallel. At the prototyping and testing stages, the solutions are represented at multiple levels using methods that represent the potential overall customer experience, as well as the physical product and organizational networks required to support value co-creation among stakeholders (Costa et al., 2017).

These methods and techniques are important to bring integrated solutions closer to the implementation stage and play an important role for companies to support the transition from product manufacturers to solution co-creators (Costa et al., 2016; Morelli & Götzen, 2016), emphasizing key characteristics of the S-D Logic along the design stages. However, further support is required for manufacturers and/or service providers to create more complete solutions, without totally shifting from product design or service design to PSS, as a full transition may not always bring additional benefits for companies (Kowalkowski et al., 2017).

To address such issue, PSS design can still bring important contributions. However, further studies are required to understand how partial PSS design infusion can enrich current design approaches such as product design and service design, to facilitate the co-creation of more complete solutions.

2.4. Analyzing product design, service design and PSS in light of the Good-Dominant logic and Service-Dominant logic

Literature review reveals important insights about product design, service design and PSS design approaches that are summarized in Figure 1. When aligning design approaches with the perspective of goods-dominant logic and the Service-Dominant Logic (Figure 1), different conclusions can be outlined:

First, product design literature has fairly evolved, going from designing isolated products, to more encompassing approaches (Ceschin & Gaziulusoy, 2016). This perspectives can be compared to the earliest PSS approaches, based on improving technical systems, making them more efficient (Aurich, Fuchs, & Wagenknecht, 2006b; Baines et al., 2009). Product design has in this regard been more aligned with a goods-dominant logic, where manufacturer/service providers create value, and customers are passive receivers and consumers. However, to create more complete solutions, product design could benefit from PSS broader view of service systems and physical products within systems.

Second, recent approaches to service design and S-D logic share the focus on value co-creation (Wetter-Edman et al., 2014). From a service perspective, value cannot be fully controlled (Kimbell, 2011) as it is created between different entities, within the customer context (Grönroos, 2011). However, service design still lacks a more robust connection to the implementation stage of the design process and should better emphasize the physical evidence and organizational components (Costa et al., 2017).

Finally, PSS has traditionally adopted a more organizational-centric perspective, more in line with a Goods-Dominant logic. However this perspective has considerably changed with recent PSS design research, which bridged PSS and service design through the S-D Logic (Costa, Patrício, & Morelli, 2015; Costa et al., 2016). This approach has been used to support manufacturing companies to transition from product to PSS solutions (Costa et al., 2017), but the implications of partial PSS infusion in product design and service design have yet to be understood and require further inquiry.

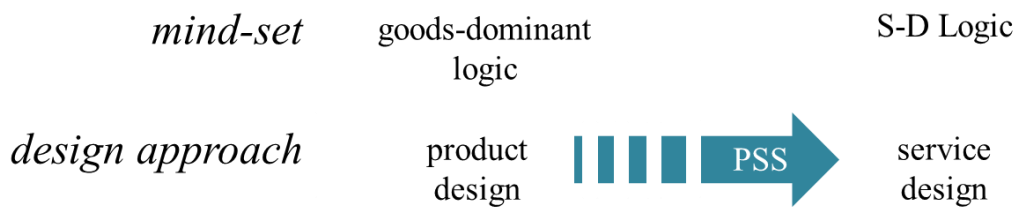

Figure 1. Analysis of mind-set and design approaches based on literature review

PSS can facilitate the co-creation of more integrated and holistic solutions that may enrich product design and service design approaches. However, there is a lack of empirical studies comparing these approaches. To address these issues, first it is important to explore product design and service design overlaps and complementarities both in theory and second, it is important to explore how PSS can enrich product design and service design approaches to co-create more complete solutions, without referring a full-transition to a PSS design approach.

To address the research gaps, this article presents a multiple case study with the following objectives: First, to examine and compare product design and service design approaches along their different stages, namely in terms of process, object design, methods and tools, as well as solutions developed. Second, to study how PSS approach can contribute to complement and/or enhance product design and service design approaches.

3. Methodology

To examine product design and service design approaches, and understand how PSS can enrich these approaches, the study adopts a multiple case study research methodology (Yin, 2003, 2014). Studying multiple cases enhances the robustness of the findings, augments external validity and helps against observer bias (Voss, Tsikriktsis, & Frohlich, 2002; Yin, 2014). Case study is adequate when “how” and “why” questions are posed, and is important to understand complex social contemporary phenomenon, within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident (Voss et al., 2002; Yin, 2003).

Given the research questions of the study, the sample of cases included 10 teams separated in two groups to enable richer qualitative inquiry, higher heterogeneity, and production of different results for predictable reasons (Voss et al., 2002). Five teams

adopted a product design approach; whereas five other teams adopted a service design approach.

The PSS design approach was formally presented to teams in both sets of cases by the end of the exploration stage and throughout the field study. The presentation focused on explaining PSS design approaches, successful cases in literature, and presenting an empirical study that aimed to co-create new integrated product-service system solutions with a manufacturing industry (Costa et al., 2015).

3.1. Case selection

The first objective of the study was to empirically examine and compare product design and service design approaches. To achieve such purpose, the cases were purposefully selected within two distinct design contexts and according to their relevance, to allow heterogeneity and richer qualitative inquiry (Voss et al., 2002).

Two sets of cases were selected which used product design and service design approaches, respectively. The first group included 5 teams exposed to a product design approach, within the Integrated Design and Management (IDM) program, at the Massachusetts Institute of Technology, United States. The second group included 5 projects exposed to a service design approach, within the New Service Development and Design (NSDD) course, at the University of Porto (UP), Portugal. Table 1 describes the design challenge of the projects. Five projects within each group were important to decrease observer bias, enabling comparison within and across cases. Moreover, it also facilitated theory building, and enhanced external validity (Voss et al., 2002).

3.2. Data collection

The field study was undertaken 4 months at IDM-MIT (Boston, USA), and 4 months at NSDD-FEUP (Porto, Portugal). Multiple qualitative data collection techniques (Neuman, 2014) were used to collect information, namely, extensive field study, observations, design presentations and reports, video recording and photographic diary to improve the reliability of the study (Voss et al., 2002). In total, 70 pages of interview transcripts, 2 diaries with field notes, different physical artefacts from projects, 10 presentations per design review (4 per design project) and official reports were the basis of the analysis.

Table 1. design projects in collaboration with companies

	projects	design challenge	in collaboration with	Business
IDM –MIT (PD-based)	P1 emergency	create a solution for emergency situation for the deaf and hard of hearing community, in cruises	experience-centric and entertainment company with cruises	B2C
	P2 online browsing	Support heavy online browsers being more efficient, while in their productive time	Browser app developer (spin-off)	B2C
	P3 travel	support travelers going through security checks in airports more efficiently	luggage manufacturer (spin-off)	B2C
	P4 music	creating a new music experience for smart-homes	sound speakers manufacturing company	B2C
	P5 shoe	explore a (short-term impact) new business/manufacturing processes for c-shoes and attract new customers	shoe manufacturing company	B2C
NSDD-UP (SD-based)	S1 energy	enhance comfort, transparency and control of energy consumption for private customers	company develops batteries to store energy and focuses on professional truck markets	B2C
	S2 garden	support public garden managers to manage gardening activities more efficiently	company uses various sensors to acquire data about weather/soil conditions; and support farmers to enhance their crops	B2B
	S3 driving	support private and professional drivers to drive more safely in long-distance trips	company which develops face recognition software to recognize sleepiness in professional truck-drivers	B2B
	S4 drones	provide a fast response to medicine transportation within hospitals	company that automates drones for transportation	B2C
	S5 gift shopping	designing a new experience for online gift shopping	company that supports SMEs to develop their online websites/shops	B2B

The field study was undertaken twice a week at MIT-IDM design lab (19 days), and once per week at NSDD-UP (13 days). Four review presentations were attended in each context. Observations were important to understand design activities, methods and tools used, and to identify the challenges faced by each team. Following guidelines of ethnographic research (Murchison, 2010), a systematic writing routine was created about the teams working on their own projects, gathering notes in-situ. In particular, the notes gathered information on: (1) the design activities undertaken both outside (e.g. meetings with the company, qualitative customer research activities) and inside the class (2) milestones and main results achieved; (3) ideas developed; (4) the usefulness of the methods and tools used by the team; and (4) design challenges outspoken during the meetings.

Semi-structured interviews with at least one member of each project were undertaken, recorded and transcribed after the projects ended. The knowledge gained during the field study facilitated the development of the interview protocol. Following recommendations of Kvale (2008) questions revolved around four topics: (1) how did the design process occur; (2) which methods, tools and/or artefacts were used and how well they supported the design activities; (3) which challenges were faced, especially when trying to integrate product and service components; and (4) how did the PSS approach influence the design process.

The interviewees had different backgrounds, and were preferably (but were not restricted to) the leaders of the project. Overall, 11 in-depth interviews were made after the design projects ended, lasting between 20 to 45 minutes each. In total, 4 managers, 10 engineers and 4 designers participated in the interview process. When possible, the interviews were undertaken in groups to obtain a more complete perspective of the project process and challenges. Two interviews were undertaken with case S5 since the leader could not participate in the first round.

3.3. Data analysis

According to Yin (2014), case description development is the most adequate analytic strategy when dealing with multiple case studies (Yin, 2014). A chronological time of the events was maintained to facilitate the analytic interpretation of phenomena (Miles & Huberman, 1994).

Following recommendations, the data was read several times (Boyatzis, 1998) and a description of each case was developed (Yin, 2014) (see Appendix III for case description). Data triangulation with different sources (interview transcripts, pictures etc.) was undertaken through a comprehensive board, structured per project and per design stage (Figure 2). This analysis of different sources of evidence aimed to improve the validity of the research results (Eisenhardt, 1989; Yin, 2014).

The research group followed an iterative process of collection, analysis, discussion of the data, and refinement of the results (Strauss & Corbin, 2015). Given the qualitative and exploratory nature of the research, data analysis progressed through time.

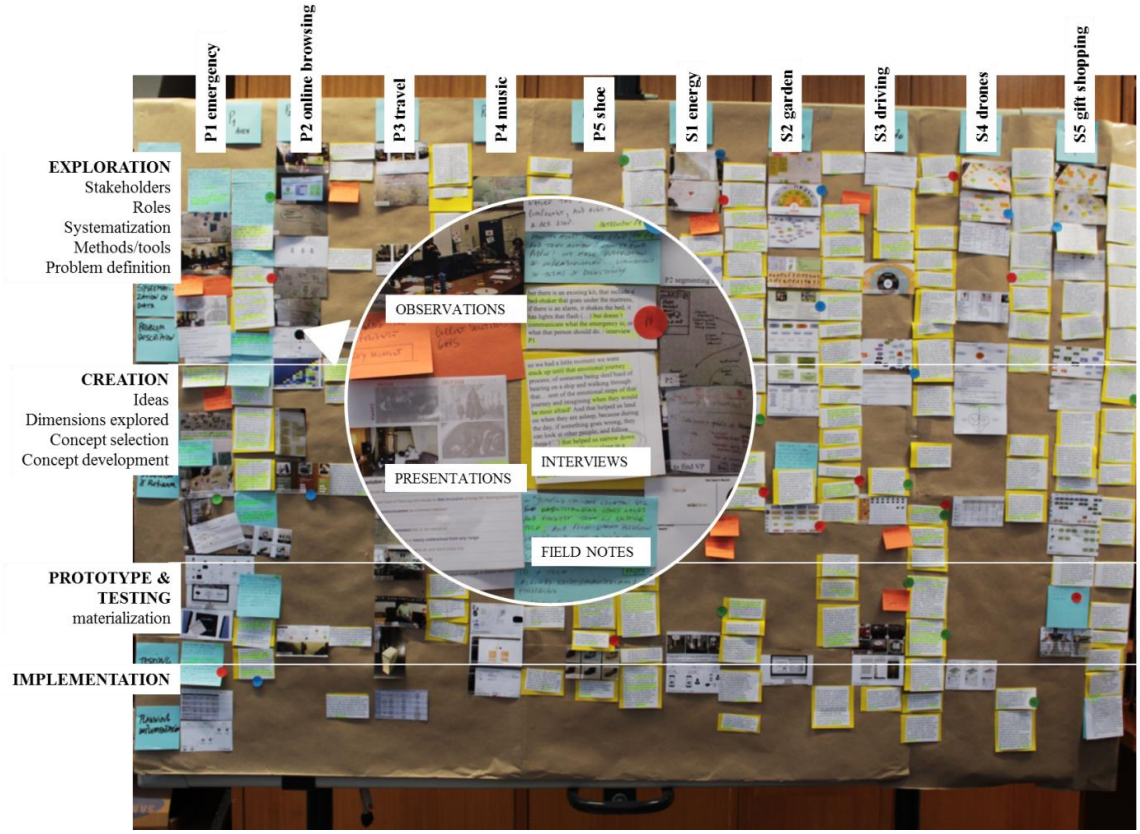

Figure 2. Supporting evidence including observations, interviews, field notes and presentations

Previous literature review showed that product design, service design and PSS design share a design thinking process – exploration, creation, prototype and test, and implementation (Brown, 2008). As such these stages were used as a framework for initial open coding. Next the evidences within each case were categorized according to their affinity to the specific characteristics of product design, service design and PSS design approaches as outlined in the literature review (see appendix I and Figure 3). The categories that emerged include stakeholders' roles, context, problem definition, product and service dimensions, materialization and organizational processes. This process was followed by constant comparison between themes within group of cases (PD- and SD-projects respectively) to identify similar or negative cases. For example, cases that would contradict a certain emerging concept would be discussed. Finally, the categories across cases where compared, and key similarities and differences emerged between PD- and SD-projects (Yin, 2014). The synthesis of the categories resulted in four main groups which are explained in the next section (results).

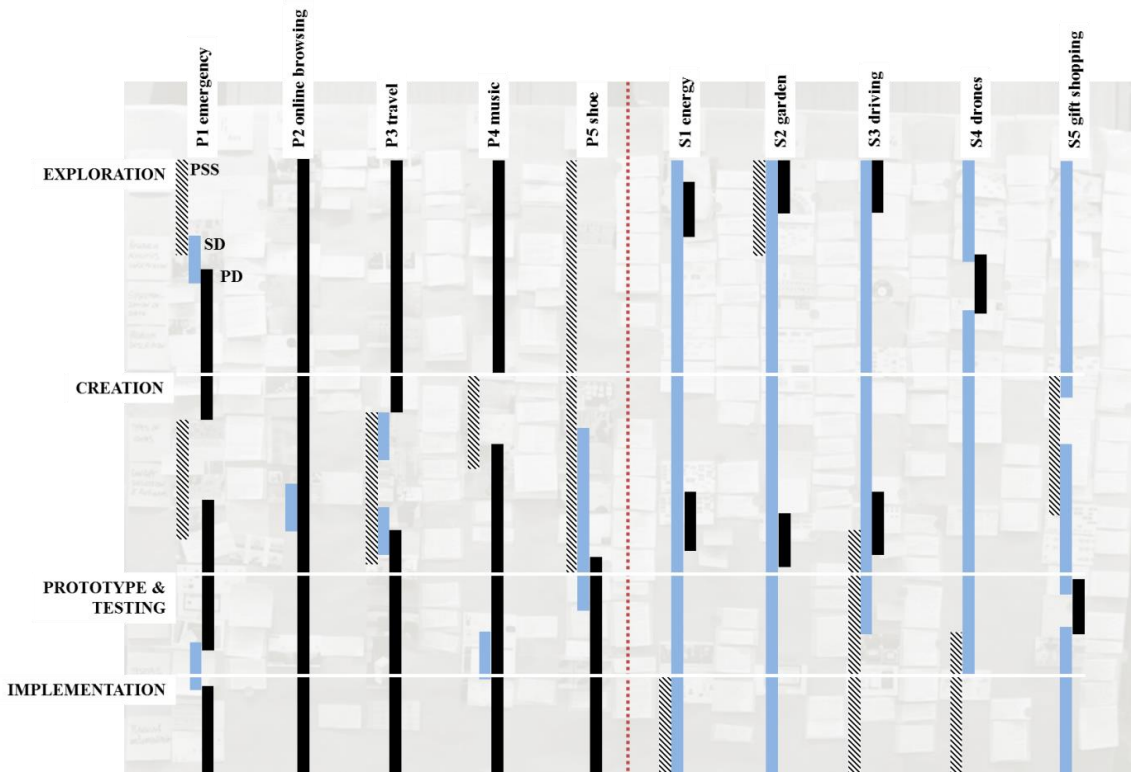

Figure 3. visual categorization of data based on the characteristics of product design (PD, stripes pattern), service design (SD, light blue color) and PSS (black) approaches

Data was analyzed across the 10 cases, outlining overlaps and complementarities between the PD- and SD- projects, responding to the first research question of the study. Next, the analysis focused on the infusion of PSS components in PD- and SD-projects, to respond to the second research question (how can PSS enrich product design and service design approaches). The composition and analysis of the data was iterated with key informants to improve validity (Yin, 2014).

4. Results

The results of data analysis were important to understand the empirical differences between design teams adopting a product design approach and a service design approach. Four main categories emerged from the iterative analysis: (1) stakeholders' role (2) design approach versus design object, (3) design context versus design space and (4) materialization of solutions. To respond to the second research question, PSS components were infused in PD- and SD-projects and the results of data analysis highlighted three major changes occurred in the projects: in PD-projects, PSS design was important to (1) support problem re-framing and (2) expand the scope of solutions;

in SD-projects, (3) PSS design facilitated the transition from service concept to implementation. The next sections explain each result in more detail, using references to the evidences in table appendix IV and V, whenever relevant to support the analysis.
Overlaps and complementarities between Product design and Service Design

4.1. Stakeholders' role

The analysis of PD- and SD-projects shows that they both adopt a human-centred approach at the initial stage of the process, identifying stakeholders and depicting their needs. However, stakeholder's identification and role definition were different between the two sets of cases.

Within PD-projects, P2 (browsing) P3 (travel) and P4 (music) adopted a typical product design approach at the initial stage of the design process, identifying potential customers, depicting their needs and problems. Although P1 and P5 were more systemic when compared to other PD-projects (they included different stakeholders at the initial stages), the personas created by all PD-projects included end-users' needs and did not encompass the needs of other stakeholders as much (appendix IV, evidence P3).
Service design enabled SD-teams to develop a broader understanding of the service system. In the cases of personas, the variety of stakeholders increased when compared to PD-cases, and so did the problems identified (appendix IV, evidence S4). For example in S4 (drone) project, the personas included pharmacist, hospital manager, and medicine distributor, which had different needs, problems and roles within the system.
On the other hand, the increase range of stakeholders considered in SD-projects also made it more challenging to define a specific customer, and frame the problem. S2 (gardens) for example, specified that it was harder to select one customer, as all stakeholders appeared to be intertwined and active co-creators of value (appendix IV, evidence S2). This is in line with Vargo & Lusch (2016) perspective of actors within service systems: boundaries between customer and service providers are blurry.

This insight reveals an important difference between product design or service design approach at the initial stage of the process. Although some PD-cases are more systemic (P1 and P5 in particular), the primary focus is usually the end-user. This perspective enables a clearer description of the problem and main beneficiary of the solution

(appendix VI, evidence P1) but it restricts the possibilities to explore the problem from more diverse viewpoints.

On the other hand, the holistic, systemic and more human-centred approach of service design enables a more comprehensive understanding of the problem in SD-projects, as it includes lenses of different actors and their own problems and needs. However, this holistic perspective may make it more challenging to define the key customers to outline the boundaries of the problem situation and to focus the design efforts (appendix VI, evidence S2).

4.2. Design approach versus Design object

Data analysis indicates that the approach used (product design or service design approach) has more influence in the design process and outcomes achieved than the initial object design (i.e. weather the design challenge focused on a product or a service). PD-projects started with no particular technology and/or device embedded within the design challenge, with the exception of P5 (shoes). This could indicate that they could obtain a more service-oriented solution.

SD-projects on the other hand, started with a technology-oriented design challenge as the companies they were collaborating with were tech start-ups. In particular, S1 included battery for energy saving; S2 included sensors for weather/soil monitoring; S3 included face recognition software; S4 included drones; and S5 included web-chat application (see Table 1).

The SD-teams that had technology and product components included in their initial design challenge, acknowledged that restricted their creative process (appendix IV, evidence S3). All the SD-projects thus attempted to detach from current solutions to reconstruct their design challenge. When transiting to the creation stage, SD-projects reframed the problem by focusing on value co-creation processes between stakeholders, understanding how their activities could be better combined (appendix IV, evidence S1). Consequently, the physical product and technology were considered as supporting elements and/or instruments to enable a new service experience (appendix IV, evidence S2).

On the other hand, the initial design challenge of PD-projects was broader than SD-projects (e.g. P3 initial design challenge was to "support travelers going through security checks in airports more efficiently"). Despite being free to develop product and service components, the teams adopted a product design approach and became more focused on solving the problem identified through technology and/or physical products. For example, P3 adopted a product design approach at the initial stage, focusing up-front on the suit-case of travelers, and how it could store things more efficiently (Annex IV, evidence P3_a). This would help the user to move objects (electronics and small beverages) more efficiently while going through the security gate, and could in turn reduce the waiting line. Their initial product design approach framed how the project was developed throughout the different stages, and shaped the solution achieved (Annex V, Table 4).

However, some PD-projects adopted a service design perspective. For example, P3 did include some service components especially in the creation stage (appendix IV, evidence P3_b), detaching from the product and acquiring a broader and more systemic view of the problem. The team discussed about stress and anxiety in airports (check-in, security gate, arriving to gate etc.) thus emphasizing the overall customer experience in the service system. The service ideas included more interactions among different service components including staff, stores and key physical spaces (appendix IV, evidence P3_c). This was observed in other teams such as P1, P4 and P5.

Although some service components were included in the creation stage in PD-projects, they were not much explored when shifting to the prototyping and testing stage. All PD-projects re-adopted a mostly product design perspective (revisit Figure 3, pg.16) returning to the exploration of material, shapes and user-product interactions (appendix IV, evidence P4). The need for validation of the solution, through robust and iterative testing was the main reason mentioned by PD-teams for focusing on products as opposed to service (appendix IV, evidence P5), so they could have a tangible prototype to test with users.

Overall, these results show that the initial object of study does not dictate the nature of the final solution. The analysis rather indicates that the design approach (product design or service design) has more influence on the way problems are interpreted and

addressed. The service design approach enabled the development of solutions focused on value co-creation processes as opposed to technology per se, emphasizing characteristics more in line with the S-D Logic. In this logic, solutions are enablers of value co-creative processes with customers. Product design projects on the other hand, tended to create solutions more focused physical products, and used service as an add-on to product offerings. This perspective emphasizes the company's role has pre-producer of value, and customer as passive receiver.

4.3. Design space VS design context

Results of data analysis showed that PD and SD-teams had different views of design space and design context. In this study, whereas design context is interpreted as things and/or components that are not changed or acted upon, design space is considered as modifiable and/or changeable. SD-teams consider interactions between service systems mostly as design space and physical products as design context. As shown in Appendix V Table 5, SD-projects looked at products mostly as pre-defined components, and focused their creative efforts on finding new connections between service systems. PD-projects on the other hand, interpreted the service system as a frame or design context, within which the new physical products and/or technology was introduced. The design space, within PD-projects, was concerned with physical products and interactions with the product.

When looking closely at the resulting solutions in PD-projects, physical product components as well as system components were included in the "contextual" category (Appendix V, table 4). In particular, P1 considered the current on-board solutions to better define their value proposition. By combining these "contextual" elements (things that already exist) and looking at the customer needs and problems, the team decided to add an element in their interpretation of design space: the TV-hack system, which would complement existing solutions (expand the design space), without changing the service system (Figure 4). P1 successfully combined product and service elements, and provided additional value to the customers, but did not change the system around which the product was used (interactions among service systems).

On the other hand, data analysis shows that SD-projects adopted a broader perspective: they considered physical products mostly in the "contextual" category, and considered

system components as modifiable, or as design space (Appendix V, Table 5). System components included combinations of technology, actors and physical. With the exception of S3 and S4, which included minor changes in the product component (Table 5), products were not changed but rather considered "as they are" in the final solution.

4.4. Materialization of solutions

When materializing the solution, the study showed that PD-projects seem to interpret value more as an experience with the product (Appendix IV, evidence P4), whereas SD-projects explored value more as the result of interactions between service systems (value as co-creation between actors) (e.g. Appendix IV, evidence S2).This is more evident in the methods and material used to explore the ideas and solutions. PD-projects used more material and form exploration (physical prototypes) to get a sense of touch, or feeling (Appendix IV, evidence P3), whereas SD-projects seem more focused on representing connections between actors, physical products, service providers and activities (Appendix IV, evidence S5).

Even though some PD-projects incorporated both product and service components in their concepts, the interviews revealed that PD-teams had more difficulty in communicating service components when compared to products. Also, the service tools were not perceived as robust enough to validate certain design assumptions (Appendix IV, evidence P5). This ultimately hampered the development of service component at the prototyping stage. For example, P3 and P5 included service components in the creation stage (e.g. P3: smart-interactive maps for monitoring time in key points in airports, P5: circular approach and online shoe customization). However, when shifting to the prototyping stage, the systemic vision tended to become lost to obtain a functional prototype. The prototypes became more focused on exploring multiple dimensions of product design and not service as much. Again, the product design approach influenced the problems addressed and the design space for solutions.

On the other hand, the interaction between stakeholders, service processes and combinations of multiple touchpoints and interfaces within service networks had a major role in SD-projects. Multiple service methods were used such as storyboards, mock-ups ups of the service interface, explaining the customer experience when interacting with the service application (Appendix IV, evidence S3). SD-projects

depicted the service concept outlining both front and back-end processes. However, the exploration of physical evidence was seldom existent. SD-projects focused on the functionality of physical products, interpreting them as instruments to support service processes. Other dimensions such as aesthetics, semiotic or hedonic dimensions (Appendix IV, evidence S4), that are typically addressed in PD-cases, where not explored in SD-cases.

This section has compared product design and service design approaches through 10 cases developing projects with companies. The next section explores the second research question of the study: how can PSS design enrich product design and service design approaches to co-create more complete solutions.

5. Bridging product design and service design approaches through PSS

As mentioned before, PSS approaches were infused in PD- and SD-projects through a presentation of the PSS approach. This introduction aimed to understand how PSS can expand product design and service design approaches, addressing the second research question of the study. Following the introduction of this approach, the study aimed to identify the elements of PSS that emerged in both PD- and SD-projects. Data analysis showed that the introduction of a PSS approach had different impact in PD-projects and SD-projects, in term of problem framing, project scope and preparation for implementation. As observed in Figure 3, PD-projects were more prone to infuse PSS components at the initial stage of the design process (exploration and creation), supporting problem re-framing in the exploration stage, and expanding the scope of ideas in the creation stage. On the other hand, PSS was more infused in later stages of the design process in SD-projects.

5.1. Problem re-framing through PSS in PD-cases at the exploration stage

The analysis on the PD-cases shows that the PSS approach has a stronger impact at exploration stage in P1 and P5 as can be seen in Figure 3 previously presented. Interviews with team members revealed that the PSS approach supported the teams to broaden their perspective and to consider more stakeholders within the service system, going beyond the user. After the infusion of PSS, P1 (emergency) and P5 (shoe) were more prone to look at problems from a more systemic perspective, when compared to the remaining PD-projects. P1 and P5 accounted other potential influencers of the

service system, looking at customer activities along the customer journey, products in service system contexts, and service processes as well.

After introducing the PSS approach, P1 (emergency) not only included the deaf and hard of hearing community (main customer or beneficiary), but also their relatives (non-deaf people) and staff of the cruise in the analysis, which enabled a broader and more comprehensive understanding of the problem. The initial design challenge was specifically aiming at emergency situations for deaf and hard of hearing community, but the team actively explored customer experiences within cruises (going beyond emergency procedures), which provided additional insights to understand the problem (Figure 3, evidence P1). P5 (shoe) team analyzed customers and non-customers' needs and problems, and depicted organizational processes as well. They tried to understand the entire ecosystem and translate those insights into potential opportunities to expand current business toward potential new ventures (Figure 3, evidence P5).

More than exploring technical problems of current products (more typical in the initial stage of the product design process), P1 and P5 were more prone to understand the system as a whole, looking at different actors as well as their role in the system, activities, interactions between other actors in the system, and problems. Thus, they acquired a more complete perspective of the realm of opportunities for product/service innovation. However, PSS infusion was not as important in other PD-teams (P2, P3 and P4). Interviews with team members revealed that the approach used in the course, as well as current expertise on product design, time pressure and expected deliverables, led PD-teams to focus the research activities on users and products, as opposed to service systems (Figure 3, evidence).

On the other hand, problem re-framing was not as evident in SD-projects, since they already adopted a broad perspective at early stages. For example, S2 included multiple potential stakeholders in their initial analysis (garden managers, gardeners, visitors as well as city halls). They understood the problems from the perspective of these different actors to better position themselves and frame the problem. In this context a PSS approach just reinforced the systemic perspective.

5.2. Expanding the scope of solutions co-created in PD-cases at the creation stage

Data analysis indicated that the PSS approach had more impact in all PD-projects in the creation stage as it enabled the teams to expand the scope of their solutions with this PSS perspective, the teams looked not only at physical product features per se, but also explored other directions more typical of service design. As such, PSS infusion was important to expand the design space beyond the refinement and/or combination of physical products.

Specifically, before PSS incorporation, P3 concepts emphasized new physical features (e.g. suit-case with new shapes). The team first listed the existing product solutions in the market, exploring shapes and small technological devices. However, after PSS infusion, the team decided to rearrange their concepts, detaching from product features, and focused more on customer activities (travelers) while in-home and while in-transit (see evidence in Figure 5). They also highlighted stakeholders' activities (airport staff) and physical space arrangement (airport key locations and bottlenecks). The combination of these different components – (activities, physical space as well as physical products) - corresponds to the PSS approach in the creation stage (Costa et al., 2017), and offers a more complete view of the solutions and its benefits for the stakeholders involved in the system.

P1 (emergency) created use-cases, and potential scenarios that would better support deaf/hard of hearing community to take action through the use of technology. The use-cases depicted the customer experience, current product solutions in-context and the interaction flow between multiple resources (actors, physical products, information etc.). By acquiring a more systemic perspective in the creation stage, the design space expanded, encompassing interactions between technological systems and users.

P4 (music) started by exploring technical problems of current solutions. However, after reaching a freezing point in the process ("it seems like everything has been done" – field notes P4), PSS infusion enabled the team to expand the design space. The team emphasized organizational components, exploring multiple business models for integrated smart-products packages (e.g. light-experience kit, home-experience, etc.), which are more typical in PSS design (Costa et al., 2017; Morelli, 2009a). This would eliminate the pain-points related with the experience of installation which was

considered as a challenge ("the fact that users do not know how to set-up the smart-products is a problem…" – field notes P4). These results corroborate product design literature as PD-teams did incorporate business components, but acquired an operational management perspective (e.g. costs of production per part) (Ulrich et al., 2011). PSS emphasizes interactions among key actors in the system, including organizational networks, which was emphasized in SD-teams.

PSS infusion was not as evident at the creation stage in SD-teams, as they were already engaged in designing service processes, and value creation interactions among different stakeholders. These activities are similar between service design and PSS design at the initial stages. The PSS approach had some impact however, in S3 (driving) and S4 (drones) cases, which emphasized more the physical products and physical spaces within their service solutions. Both teams included minor changes in the products to better support the service experience (e.g. "(…) we made some mock-ups with that (medicine) to capture the behavior of the drone when it's flying" interview S4). Also, S5 infused some PSS component at the creation stage by exploring business models that would in turn result in different value propositions.

5.3. Bringing service concepts closer to the implementation stage in SD-cases

The analysis of SD-cases showed that the PSS approach tended to be more infused in later stages of the design process (Figure 3). Although the projects did not fully reach the implementation stage, they considered aspects that are typical of implementation. S1 (energy) value proposition was to offer comfort, transparency, but also savings for customers through the use of batteries. However, the current battery prices are still high. Based on this insight, they created a roadmap consisting of three major stages: basic, green and advanced package as can be seen in Figure 5, evidence S1). The evolving nature of the value proposition through time, with physical products and service system interactions, is more evident in the PSS approach (Cardona et al., 2014). S1 project integrated this aspect of PSS by combining the use of smart-devices and information, with service interfaces, actors and evolution of markets and technology.

S3 (driving) and S4 (drones) projects also used PSS component to better prepare for the implementation stage. The combination of physical space, service system interactions, and the key product components is more typical in PSS design. Both cases looked at the

service processes and intended customer experience to understand the changes required in the physical products. For example, S3 specifically mentioned that the service would not function properly without a physical support (Figure 5, evidence S3). S4 also proposed changes in the current drone as the service was purposefully designed for fast in-door medicine transportation (Figure 5, evidence S4).

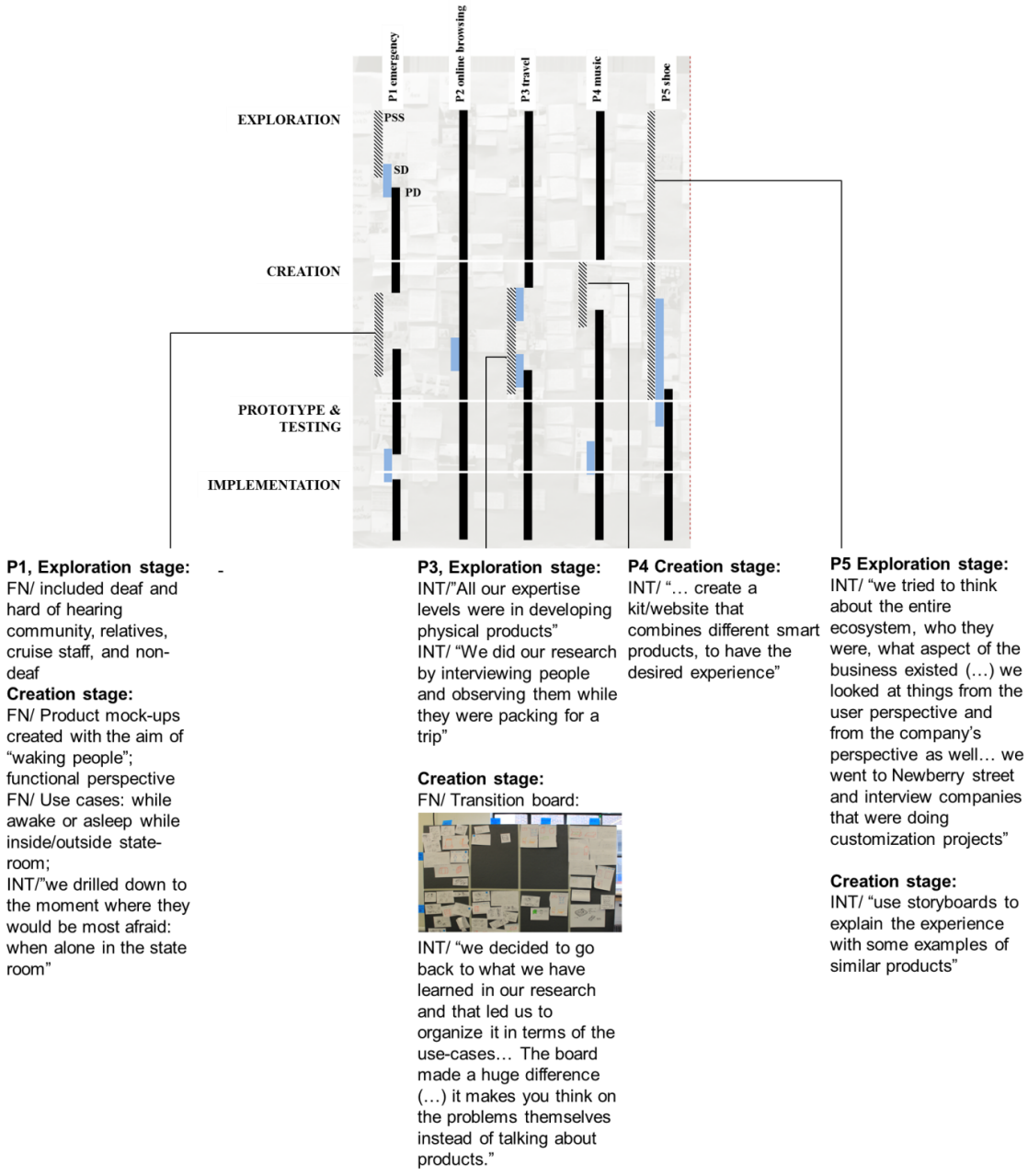

Figure 5. Evidences of PSS infusion in PD-cases

Additionally, S4 proposed exploring renting or leasing business models for the technology, and found a pilot-case study to incubate and refine the solution. Pilot case

studies in PSS are important to understand changes in customer practices, enhance the integration between the multiple evidences, and define potential business models (Ceschin, 2014). S4 used the case to refine the business model, and reach the implementation stage.

Overall, the data analysis indicates how PSS components can enrich PD- and SD-projects and in which stages it can have the most impact. These insights can be used in future projects service design and product design projects to support the design of more integrated solutions without a full transition towards a PSS design approach. The next section discusses the results and outlined the main contributions of the study.

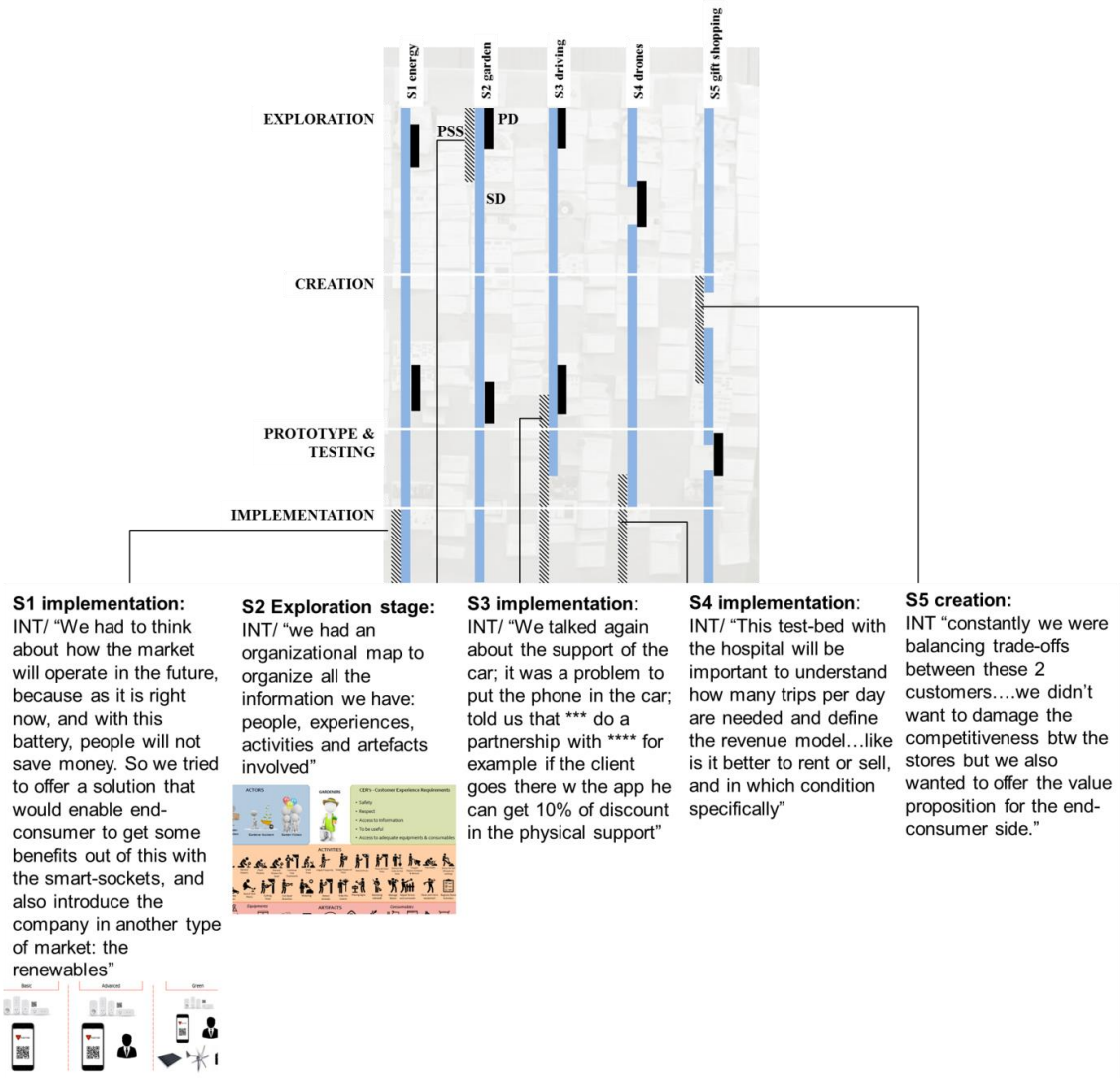

Figure 6. Evidences of PSS infusion in SD-based cases

6. Discussion

This paper presents a multiple case study with 5 PD- and 5 SD-projects. First, it compares product design and service design approaches based on literature review and an empirical study. Second, the study examines how a PSS approach may influence the design process and design outcomes (solutions) of PD- and SD-projects. Recent research indicates that full transition towards PSS can be risky and may not always be beneficial for companies (Baines et al., 2017; Baines et al., 2009; Kowalkowski et al., 2017). PSS approaches have evolved considerably, encompassing more human-centred and co-creative perspectives, focused on value co-creation, and organizational network components (Costa et al., 2016). These approaches have been important to support the co-creation of more integrated solutions in companies (Costa et al., 2017). However, partial infusion of PSS in the design process can still support companies to create more integrated solutions without a full transition. However, it is unclear how it can enrich product design and service design approaches.

Dealing with a design task in "messy" situations constitutes the everyday context of design practice (Buchanan, 1992; Stolterman, 2008). Understanding how companies can identify the gaps of the design approaches they adopt will support them integrating complementary perspectives whenever necessary, and ultimately facilitate the co-creation of more complete solutions. This study compares and brings forward important complementarities and gaps between product design and service design approaches. In particular the study outlines four categories: (1) stakeholders' role, (2) design approach versus design object, (3) design space versus design context and (4) materialization of solutions.

First, regarding stakeholders' role, the PD-projects tended to focus on the dyadic relationship between users and the company. Customers and product/service providers have clear roles, which resonate more with the goods-dominant logic where value is pre-produced by companies, and customers have a more passive role.

6.1. Contribution to better understand product design and service design approaches

The study results show that SD-projects acquired a more holistic perspective, but had more difficulties defining the main customer of the solution when compared with PD-

cases. These results showed that product design can therefore benefit from acquiring a broader perspective at the initial stages of the design process to better understand the problems within service systems. Service design on the other hand, can also benefit from emphasizing more the physical evidences along the service experience and physical space, to facilitate problem framing.

Second, the results indicate that the solutions developed by the teams can be more influenced by the approach adopted (product design or service design) rather than the initial object of study (design challenge). Although the design challenge of PD-cases was more systemic at the initial stage, they tended to create mostly product-oriented solutions. SD-cases' initial challenge were more technological-based, but all SD-projects created mostly service-oriented solutions. This indicates that it is more the approach that shapes the object of study (product or service) rather than the opposite. Product design approach may take into account systemic aspects, but will tend to focus more on product components to solve problems. Also, regardless of the initial object of study or design challenge, service design approach will understand the importance of the functional usefulness of products, but will tend to focus on service systems to solve problems.

Third, regarding the design space and design context, the application of the approaches led to (1) development of new products considering service systems as contextual components; or (2) development of new services, focused on resource reconfiguration, considering the product contextual components. Whereas the first perspective was more emphasized in PD-projects, the second perspective was more emphasized in SD-projects. Again, the approach shaped how the components are interpreted and which are considered as changeable and those that are fixed, or not acted upon.

Fourth, regarding the materialization of solutions, the empirical analysis supports literature review. Product and service dimensions explored in the creation, prototype and testing stages differ in the two groups, as SD-projects tended to focus more on the functional usefulness of products, using them as instruments to support value co-creation processes. PD-projects on the other hand focused more on multiple dimensions of products, and not so much on service, especially when shifting to the prototyping

stage. This contributes to understand how each approach focuses on certain dimensions, which ultimately shape the solution.

The findings discussed in this section advance product design and service design research by exploring their overlaps and complementarities which were not identified before. This contributes to design research and practice, to better understand how these approaches can complement each other whenever new product and service components need to be integrated to support value co-creation (Baines et al., 2017; Ostrom et al., 2017).

6.2. Contribution to understand how PSS can enrich product design and service design

Additionally, the study also outlines the potential benefits of infusing PSS components in product design and service design approaches. The application of PSS approach in different design cases showed how PSS can support problem reframing and expand the scope of analysis of PD-projects. On the other hand, service design stills needs to mature in later stages of the design process, paying more attention to organizational issues (Sangiorgi & Prendiville, 2014). PSS infusion in SD-projects can facilitate the teams to consider more aspects related to the implementation stage, by looking at business models, and physical evidences embedded in service in more detail.

As result analysis indicates, product design approach can create system-level innovations when integrated with PSS (e.g. P1, P3 and P4 or P5 at the creation stage). On the other hand, although only two SD-cases considered physical products as design space (S3 and S4), service design could also trigger product-level innovations by emphasizing more physical products in service. As such both service design and product design can enrich and complement each other, and a PSS approach can help operationalizing these complementarities.

The findings discussed in this paper contribute to advance product design and service design research by exploring the stages in which these approaches can be enriched through the PSS approach to better support the co-creation more integrated and systemic solutions.

7. Conclusions and Future Research

Product design, service design and PSS design research are facing increasing challenges particularly in regard to designing more integrated solutions (Baines et al., 2017; Ostrom et al., 2017). Manufacturers are infusing more service in their product offerings, and service companies also pay additional attention to the multiple physical elements within service, but they need more support to develop more integrated solutions for their customers. This research addresses these challenges by outlining key empirical differences between product design approach and a service design approach, and exploring how partial PSS infusion can enrich these approaches. The results of the multiple case study shows that PSS was able to enrich the design process of both approaches although without losing the focus on product design and service design.

The study also has limitations and indicates future research directions. First, the cases were limited to 10 projects. The 5 SD-projects were in collaboration with technology-based companies which may not be totally representative of service industries. Future research with service companies or public services, with a focus on value co-creation between actors and customers, represent a fertile ground to better understand the challenges of combining product design and service design as well as the implications of infusing PSS in these design approaches.

Future research of design approaches could also include the combination of multiple components of product design, service design and PSS design. Designing service systems is a contemporary issue and a significant challenge. Understanding how to address increasing levels of complexity in product, service and systems is important to better support value co-creation amongst service systems, from micro- to macro-levels. More studies on the differences and complementarities between product design, service design and PSS design could enrich the results of the present study, to understand their strengths and weaknesses, as well as the context within which they work better, to create more complete solutions. Moreover, this study shows that more than designing a product and service, what differentiates is whether the team designs a solution with a product design perspective and a service design perspective, which indicates that it can always be useful to adopt partial approaches as they bring complementary perspective to design solutions. Future research could explore how these approaches should intertwine to better support value co-creative processes.

Our findings are in line with the important challenges of designing more integrated, and systemic solutions. The research hopefully contributes to advance our understanding on how partial PSS infusion can better support the design of more integrated solutions in both product design and service design projects.

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Appendix I comparing PD, SD and PSS

Figure 7.comparing PD, SD and PSS approaches

Appendix II case selection

Case selection

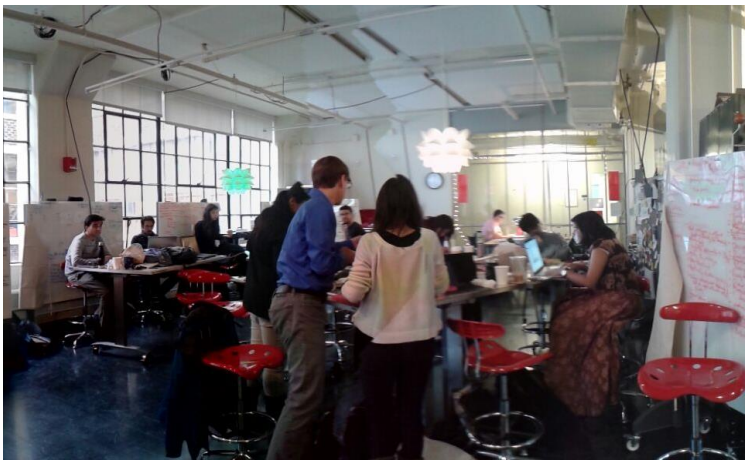


Figure 8. PD-based projects at IDM-MIT, Boston, USA/ objective of the program is to Integrate design, engineering and business disciplines to solve complex and hard-to-define problems and create new products

Figure 9. SD-based projects at MESG-FEUP, Porto, Portugal/ objective of the program is to Develop competencies to create, design, implement and operate technology-based service systems solutions

Table 2. design reviews

	PD-projects IDM-MIT	***SD-projects MESG-FEUP***
(0)	Presentation of company's pitch and design challenge	
(1)	explain the problem framing, benchmarking research, such as the results from customer research	mission statement: explaining the culture and business of the company; and potential design challenge;
(2)	present the concepts obtained, methods and process followed; and selection criteria. Explain the business model	understanding customer experiences: contextualize project; systematization of results, benchmarking
(3)	Detail the solution, present potential failures and tests undertaken; and further detail business model	service concept, defining the potential value proposition(s), partnerships; and present the service system design
(4)	overview of the entire design process and presentation of the product solution such as the potential business model	prototype the customer experience; and include people, processes and physical evidence, and connection with partners

Data collection

Table 3. interviewees per case

	team	***# interviewees***	***background***	***time***
IDM –MIT	P1	1	1 business management	20 min
	P2	1	1 designer	45 min
	P3	1	1 designer	30 min
	P4	1	1 engineer	30 min
	P5	1	1 business management	40 min
MESG-FEUP	S1	1	1 engineer	30 min
	S2	4	3 engineers; 1 designer	45 min
	S3	2	2 engineer	40 min
	S4	3	1 economic management 2 engineers	20 min
	S5	2 + 1	1 engineer + 1 marketing management 1 designer	30 + 30 min

Appendix III case description

P1/emergency design challenge focused on creating an effective solution to support deaf and hard of hearing community to evacuate cruises during emergency situations. The team included different stakeholders in the DP (cruise staff, deaf community, parent, friends etc). They adopted a broad approach to understand the problem situation, trying to depict the regular activities of the deaf/hard of hearing community in cruises and looked at the different solutions and products in-context, identifying their gaps. When systematizing the findings, they created 4 use cases which they downside to one: when alone, in the state-room. Through participatory approaches, two main ideas were developed and tested iteratively: wearable bracelet with a vibration system, and a TV-hack alert system. The team used mock-ups and storytelling techniques to communicate the solution to the community. Finally, after refining the solution, the final prototype was developed with the attached service component. The service per se was described as "informing people about the existing emergency, and tell them what to do". The solution would complement existing ones already installed in state-rooms (e.g. bed shaker). The team also developed a cash flow analysis of their product sales.

P2/online browsing design challenge was to support online community to make a more productive use of the internet. They started with a broad sample, launching a survey online which would capture every 3 hours the webpage visited, the mental-state of the user such as demographic information. After much iteration and information analysis, the team reached the conclusion that browsers, especially heavy browsers are not satisfied with the endless google searching for answers that they could nt find. Three weeks before finishing the project, they developed 3 personas which were characterized by profession and objective in google-search (e.g. Ajan, from India, entrepreneur that wants to plan a trip to Europe) and developed storyboards explaining how their online application would help them being efficient. The team showed the functions of the website (e.g. downgrade/upgrade of certain websites, collection of webpages that could be shared with the community), but did not developed specific aesthetics of the online website. Moreover, there was a specific concern with the business model of the solution.

P3/travel design challenge focused on supporting traveller going through security check faster in airports. For this, they focused their effort in making a luggage that would help

users to access and organize their items in a rapid way. The exploration stage included simulations of airport checks, interviews, observations etc. focused in luggage use throughout the trip: pre-trip, outbound, during trip, returning; and post-trip. Concept generation included pieces of technology that could be attached to existing luggage, or new luggage. Through the application of PSS principles, the team was able to look at the system from a broader perspective, re-structuring their concept generation board, from "products" to "activities". Although achieving broader concepts and exploring service components, such as interactions and time dimensions, the team narrowed their solution the product component and dedicated their remaining time to the development of fine refinement of the physical prototype. Service component was included only as a marketing exercise (post-sales support).

P4/music design challenge was to create a new music experience for smart-homes. They started the exploration process focusing on lead users of smart tech, looking at current technologies as well. The team identified scattered and non-integrated smart-devices that would require an overwhelming amount of pre-configuration or smart-phone applications to work. In the creation stage, they talked about services that could sell pre-made and ready to install packages of smart-products for a desired experience. However, they were required to first define the experience and were challenged to scribble scenarios or use-cases. The team jumped to the prototype and form exploration "we want to eliminate smartphone use". After defining the user-product interaction, and detailing mechanisms and electronics, the team attached a service to the product that would collect information from wearables in a way that would enable the device to "read emotions" and play the music accordingly. However, the service component was not very detailed.

P5/shoe design challenge was to provide a creative and innovative new business process, consistent with company's brand, that didn't require changing the shoe and increased sales. The exploration process started with a systemic approach, looking both at the company's capabilities and partnerships, current technologies and also at users' needs and problems. They identified early on different opportunities that they explored in parallel until the prototyping stage: local production, customization, up/recycling process of leather and distributed manufacturing. They looked closely at the changes of the business model for each opportunity. The team developed storyboards but felt that

the concepts were not robust enough to pursue as many assumptions about the service could not be validated. In the prototyping stage, the effort drilled down to the exploration of form, shape and materials of the product (shoe sole from leather scraps). Although the service component was not further detailed, the upcycling process was introduced by the manufacturer.

S1/energy design challenge was to enhance the control of energy for end-consumers. The team identified different stakeholders within the energy service system. They focused effort in trying to understand the different activities in the household that would relate to energy consumption and have understood that consumers were interested in saving money. After benchmarking research and synthetising the research diaries, they found that the current battery/technology (product of the company) would not be able to save money, as such they looked at the energy future market to develop their solution. They have developed a roadmap that would introduce the company they were working in the energy sector. First, do-it-yourself package would include smart-sockets from the company plus the A*** application to help monitor and control energy in the house. Second, they developed a consultancy service; and finally, they included renewable products within their solution. The solutions would at last have implications for the business model of the company.

S2/garden design challenge focus on exploring the gardening sector (other than crops), and understand how to manage gardening activities. The team focused in public gardens and focused their activities in identifying stakeholders of the public garden (gardeners, managers, visitors) depict their activities, problems, such as typical artifacts used. The team felt much difficulty in organizing information as they felt that the 3 stakeholders identified were very connected. Their main idea focused in creating an overall solution for the 3, however they were unclear on the value proposition, and how this idea would be beneficial for the company they were working with. When downsizing to the prototyping stage, the team selected one customer (garden manager) and looked more closely at their needs, developing an application that could support the distribution of tasks and gardening materials through the various gardeners.

S3/driving design challenge support safe driving in long-distance trips. They first have restricted their exploration research activities to understanding how customer interacted

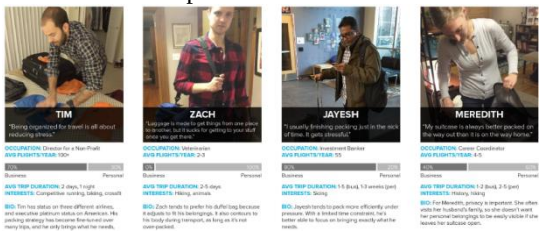
with the current app of the company (face recognition software that would beep when detecting sleepiness). After realizing that it restricted their perspective, they looked at the different activities that drivers would do to avoid falling asleep while driving. They created a model which would synthesize information on current solutions, infrastructures/context and drivers' emotions. They focused on the development of an app that would connect drivers with personal and professional communities. First, in case of sleepiness detected by the face recognition software, the application would emit a customized sound up to 3 times, after which it would automatically call an emergency number pre-defined by the driver. The app would also have connections to different hostels/restaurants that could be reached and rated as a "place to stop and rest". The team detected the use of the app to have several problems namely the use of a support inside the car to facilitate proper face recognition. The car-support component would be sold in retailers but would not be produced by the company itself.

S4/drones design challenge was to facilitate urgent medicine transportation. The team collaborated with a drone company that wanted to expand the business. The team identified different stakeholders: hospitals, pharmacies, medicine distributors, health centres. After the first interviews, the team decided to focus on hospitals, which showed most interest. The benchmarking showed parallel transportation options (motorcycle, standard truck delivery etc.), which was useful to better define the value proposition. Qualitative research activities were undertaken with 3 stakeholders of the solution to identify problems and needs (pharmacists, hospital staff and director and distribution companies). Because of tight air-flight regulations in public spaces, the solution was developed within hospital facilities. The team managed to find a real use-case to test and refine the service which was to facilitate urgent medicine transportation between departments, inside the hospital. The team also considered different business models for potential future implementation namely, renting or leasing the drone.

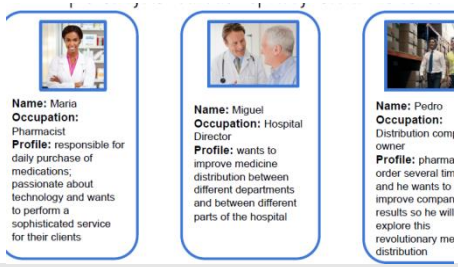
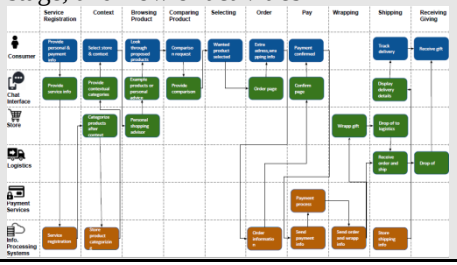
S5/online shopping design challenge was to support online gift shopping through chat application. The team undertook an online survey and interviews to customers of the company (SMEs) and end-consumers (clients of the SMEs) to understand their activities and experiences. Interviews to competitive companies were also undertaken. A benchmarking research enabled the team to understand how different chat applications would respond to different customers' needs. The team restricted its analysis to chat

apps (ie. solution) as the company insisted in using such application. From the research, the team identified gift shopping to be a potential opportunity not yet widespread in the current market of the company (South America). Two main services were developed: the first one would gather gifts from different shops into one online platform that would work with different filters (e.g. birthday, marriage etc.); the second would be organized per shop (e.g. apple, zara etc.). After entering the shop, the chat app would initiate, thus providing advices in terms of the best gift to offer, according to the customer input (e.g. age of receiver, occasion etc.).

Appendix IV multiple evidences

Case	Stakeholders role	Approach VS object	Materialization
P1	INTERVIEW/P1 “our solution aims to warn deaf and hard of hearing community about the existing danger on-board”	FN/P1The team talked with community about current concepts: “works pretty well”. They reviewed the pool of ideas, “if the point is displaying info then, there’s already a display in every room: the TV. We want to avoid redundancy. We can also use the alarm to activate the info display” Team starts brainstorming concepts focused in hacking the TV only.	
P2			
P3	FIELNOTES/P3 personas 	INTERVIEW_a/P3 “we wanted to understand how people pack and organize themselves to get through security line (…) listing the objects that already exist kind of closed our mins (…) we ended up focusing our efforts in how the research can best inform the redesign of a product that would help people to get through airport security faster” INTERVIEW_b/P3: “We talked about having gps; having bluetooth that connects to your phone tell you were the luggage is; you could have a digital lock that you could have lock/unlock your luggage.” FIELDNOTES_c/P3 “let’s inform the customer about potential queues and timing in determined locations through an integrated online app for example”	FIELDNOTES/P3 exploring shapes, materials and access to items in luggage 
P4		FIELDNOTES/P4 exploring mechanical and electronic components for the remote 	INTERVIEW/P4 “We wanted a way to relay emotional feedback via some physical product (…) In so far as we had product (remote control) that we can push play on and it would play in the speaker. The rest is like the idea… again because we do not have coders… we can do blue-sky ideas about what we want to data to deliver”

P5	INTERVIEW/P5 “we did a pretty extensive amount of work in terms of thinking about the entire ecosystem, in terms of how they were, what aspects of their business existed (…) we looked at things from the user perspective and from the company perspective”	INTERVIEW P5 “obviously during the design process you want to validate or invalidate assumptions (…) we just went for the product because we gotten enough early validation that we could actually accomplish it”	INTERVIEW/P5 “(…) storyboarding really fell down for me. It just wasn’t very convincing. I told the story but people were like yeah i don’t really see how this could possibly work… plus relaying on so many future assumptions like 3D printing as commodity?… how were we supposed to validate a service around distributed and customized manufacturing and this?(...)”
S1		INTERVIEW/S1 “we first focused on the battery (…) but when we realized it does not help actually saving money… we were like… ok so this project doesn’t make sense anymore?... finally we decided to think broader (…) we asked (to customers) do you think you spend a lot of money on energy? They would reply “I dunno”. So this is where we want to focus on: why don’t they know? How can we make this clearer for them?”	
S2	**INTERVIEW/S2 “**So we always have three main actors and they are all integrated **(…)**… we had difficulties in separating them and organizing the information”	INTERVIEW/S2 “…the idea is using smartphones for example. Engage with customers through the smartphone… the user can take a picture of damage property and send it to the garden city hall” interview S2	INTERVIEW/S2 “What we would like to explore is to give the app to the customer (visitor) one that is similar to the gardener…create a connection line between the 3 stakeholders and connect the visitors directly to the management and… trying to avoid the management having to go everywhere to see what happens because the public can help”
S3		INTERVIEW/S3 “since the beginning we were thinking about the solution already and not understanding the problem; and we are focused in the product and not in the service; the app that they had … we put people experiencing the product	PRESENTATION/S3 service architecture and storyboards 

S4	FN/S4 personas included: pharmacist, hospital manager, and medicine distribution manufacturer 	INTERVIEW/S4: “the software is made out of the customers’ needs and wants it’s not a lot of imagination; and the drone itself is done within what is possible to do”.
S5		PRESENTATION/S5 Service architecture representing connections between front- and back-stage, and flow of activities 

Appendix V solutions obtained

Table 4. PD-based projects: design outcomes, (1) key contextual artefacts are either product or service components that were considered for the solution to function, but were not modified/acted upon, (2) the physical product components are developed and/or require modifications, (3) the network component included actors that would support value co-creative processes and (4) the service component included the supporting processes, service interface, software etc. of the solution.

	P1 emergency	***P2 browsing***	***P3 travel***	***P4 music***	***P5 shoe***
Contextual artifacts	bed shaker; cruise emergency system	computer	-	Sound speakers; Wearables; biometric information systems; Calendar events	Shoe
Physical product	Tv-hack Black-box; Universal digital signage;	-	Suit-case case	Remote control	Shoe sole with shredded leather
Network	-	Hosting website; Google engine search; Browsing community	-	-	Manufacturing up-cycling process
Service component	Sound-recognition software	Web-page collection management software	maintenance and repair services	Emotions-based music management software	-
Type of solution	Mostly service with supporting product component	Mostly service	Mostly product	Product with some service	Mostly product
Brief description	Plug-and-play black-box connected to the cruise TV-room, which activates through the alarm sound. System displays universal emergency content.	online application that supports online browsers to curate their web content by upward-downward web pages; collection of theme-based webpages	new high-quality suit-case with access its content through the top and sides	Portable smart and touch- based remote control for music attached to biometric information systems of wearables, selects the "right" music for the user.	New upcycling manufacturing process for soles that uses cold molding compression of resins and leather shreds.
					

Table 5. SD-based projects: design outcomes

	S1 energy	***S2 gardens***	***S3 driving***	***S4 drones***	***S5 online shopping***
Contextual artifacts	Home appliances; Sensors; Smart-sockets	Computer; Smart-phone;	-	Medicine	Online articles; Gift box; Gift ticket
Physical product	-	-	Consider smartphone support	Consider transportation box for medicine	-
Network	Energy distributors; Renewable energy systems providers	Public gardens; city halls; Gardeners teams;	Hotels/motels; Gas stations; Google maps; Drivers community	Hospitals Pharmacies Regulation laws; Security regulations; Drone operators	Small and medium companies; Hosting website; Transportation services;
Service component	management service software; consultancy services;	seasons-based gardening activity management software;	face recognition software; driving control service system; rewarding service system;	Medicine management software; Drone training services; Pay-per-flight business contract	Gift selection and delivery service system application
Type of solution	Mostly service	Mostly service	Mostly service	Mostly service with supporting product component	Mostly service
Brief description	App that enhances transparency and control over home appliances, provide bill status, makes historical comparisons, alerts, identify malfunctions and broken equipment.	Web-based service platform for managers to schedule activity by month/week and tasks of reported problems, checking work real-time, controlling tools/equipment used/available.	Iintegrated app that supports safe driving in long-distance trips. According to the level of the alert, the app suggests stopping spots (hotels, restaurants), calls a friend, and has a rewarding system for long-term users.	App that enables to access medicine transportation through drones services within hospitals; App provides information on drone position, battery, load, and weather conditions	Online chatting platform service that support customer in gift shopping; customer selects the store, provides information about the gift receiver, providers suggests gifts. Gift is sent to the receiver.
					

5. CONTRIBUTIONS

Designing integrated good-service solutions has been identified as a research priority in both PSS (Baines et al., 2017) and Service research literature (Ostrom et al., 2015). PSS and Service Design approaches are complementary perspectives to conceptualize new solutions but they have yet to be integrated. Moreover, both research fields have important challenges that need to be overcome. On the one hand, PSS literature outlines two main issues in particular customer acceptance of integrated solutions (Rexfelt & af Ornäs, 2009), and PSS infusion in companies (Baines et al., 2017). On the other hand, to co-create positive customers experiences, Service Design needs to expand towards later stages of the design thinking process i.e. implementation stage (Yu & Sangiorgi, 2017), and better emphasize the physical evidence within service solutions (Berry, Shankar, Parish, Cadwallader, & Dotzel, 2006).

To address these challenges, we have employed a design research methodology (Cross, 2001, 2006; Dorst & Cross, 2001; Fallman, 2008), combining different perspectives of design research i.e. design research to create new artifacts (Hevner et al., 2004; Manzini, 2008; Zimmerman & Forlizzi, 2008), and design research to study design phenomena (Fallman, 2008; Yin, 2014). The outputs contribute to enhance the PSS research by expanding the toolbox dedicated to integrating processes, product and service components, as well as interfaces, people and organizational-networks. It also contributes to better understand how PSS can be infused in different companies' design process.

The thesis offers three main contributions, namely: (1) development of a conceptual framework that bridges PSS and Service Design that can ground future research at the intersection of PSS and Service Design and S-D Logic, (2) development of an end-to-end approach (integrative PSS approach) as well as design models, that leverage contributions of both PSS and Service Design and (3) analyzes product design and service design, outlining the critical stages where PSS enriches Product Design and Service Design, contributing for the expansion of these design approaches to more integrated and solution-oriented mind-set. The following sections discuss the contributions more in detail.

5.1. Contribution to integrate PSS and Service Design perspectives and create a conceptual framework

The first contribution (Costa et al., 2016) responds to the call of Baines et al. (2017) to support manufacturers moving beyond the traditional view of service as add-on to physical products, and adopt a perspective more focused on value co-creation processes, in particular the S-D Logic (Baines et al., 2017). S-D Logic is outlined as a new perspective of service that has grown rapidly in service research (Vargo & Lusch, 2008, 2016). However, it has been little explored within the manufacturing context (Baines et al., 2017).

By adopting S-D logic as a lens, the integrated conceptual framework supports the integration of PSS and Service Design, which have different backgrounds and different perspectives regarding value co-creation. PSS adopts a more organizational-oriented view, whereas Service Design is more human-centered and co-creative. PSS views customers as more passive, and interprets value has co-created within organizational-networks (Baines et al., 2007; Baines, Lightfoot, Benedettini, & Kay, 2009). As such, from this perspective, the organization has more control over the value co-creation process. From a Service Design perspective, on the other hand, customers have a central role and the service cannot be fully predicted (Kimbell, 2011). The organization has limited control of the co-production process with the customer, and can only offer value propositions (Wetter-Edman et al., 2014).

The overview of PSS and Service Design identifies a lack of a full overlap of terminology. However, the study shoes several complementary characteristics. Based on these insights, the framework creates a unifying language, outlining potential synergies between disciplines that were not previously integrated; and can support the development of future research that lies at the intersection of PSS, Service Design and S-D Logic. As such it contributes to better design integrated solutions, with a focus on value co-creation.

5.2. Contribution to develop a new integrated PSS approach and enhance design models

The second study responds to the call to design new PSS methods to support manufacturers in designing new solutions, facilitating the servitization process and service infusion (Ostrom et al., 2015). Study 2 develops an integrative PSS approach and set of models, and shows how it can be used to design new integrated product-service system solutions in manufacturing companies, through a case application to a smart-lab project.

The definition of the value proposition is a very significant challenge in PSS (Baines et al., 2017; Raddats et al., 2016) and often customer experience and emotions are not well integrated in the design process (Carreira et al., 2013; Stacey & Tether, 2014). The new integrative PSS approach and models address these gaps by supporting the design of integrated solutions, from the exploration of customer experience, to the creation of more integrated solutions and better prepare for the implementation stage, combining PSS organizational-network oriented perspective with the Service Design human-centered approach. The integrative PSS approach is a systematized process, which contributes to smooth the transition between the different design stages.

In the exploration stage, the extended CEM evolves current service design model CEM (Teixeira et al., 2012) and uses similar language to facilitate communication and analysis of the customer experience among different stakeholders. The extended CEM supports manufacturers to better understand how their offerings are positioned in the value constellation of services, and how their products affect the holistic customer experience.

In the creation stage, three new PSS models support the definition of the value proposition, considering customer experiences, stakeholders' resources and organizational components. The PSS constellation, PSS value matrix and PSS architecture models enable a multilevel perspective of the new integrated offering, combining the complex elements that shape the customer experience and organizational components in an integrated way. The PSS constellation evolves the Customer Value Constellation (Patrício et al., 2011), and enriches the representation of the service

concept. This model fosters creativity and generation of new ideas through the use diagrams which emphasize physical resources and technologies that support value co-creation processes. The PSS value matrix complements the PSS constellation, outlining key characteristics of equipment, technologies and other resources to offer value propositions to customers. This helps manufacturers to understand the key features that need to be integrated in physical products, and proceed with product design and development activities in unison with the overall PSS concept. The PSS Navigation evolves the Service System Navigation (Patrício et al., 2011), combining rich visual information of storyboards with information about the orchestration of multiple PSS resources. This representation enables fruitful discussion about the intended PSS experience and outlines possible breakpoints in product and service components.

The prototyping stage offers an approach to represent the customer experience within PSS, combining storyboards and physical prototypes. This is a low cost and effective approach for the company to understand PSS experience, enabling rich customer feedback on both product and service components. Finally, the PSS Organizational Network Map combines the visualization to previous models to support a smoother analysis of the system and organizational network components.

The new integrative PSS approach contributes over other PSS and Service Design models (Patrício et al., 2011; Teixeira et al., 2017) by embedding customer experience and organizational network component across the different stages of the design process, and emphasizing the importance of physical product and service components in PSS. It better supports PSS infusion within manufacturing industry through a multilevel approach and guideline. The integrative PSS approach and models support the co-creation of solutions that can enable smooth customer experience with integrated solutions, while also looking at the necessary components to implement the solution in context.

5.3. Contribution understand the potential of PSS to enrich Product Design and Service Design practices and processes

Having created new models and systematized a new integrative PSS approach, the third objective of the thesis was to understand how PSS can enrich Product Design and Service Design approaches, without a full-transition to PSS. Previous literature explores

the infusion of services within manufacturing industry but lacks on contributions of alternative strategies where physical evidences are emphasized in service offerings (Baines et al., 2017). Physical evidences need to be designed from an integrated perspective to enable smooth customer experiences (Berry L. et al., 2006). The multiple case study contributes to enhance research validity, enables higher heterogeneity and richer research results (Voss et al., 2002).

Service research explores the difference between product and service (Edvardsson et al., 2005). However limited knowledge exists about the gaps and complementarities between Product Design and Service Design approaches. Study 3 responds to Baines et al. (2017) call regarding the lack of studies on service industries, and contributes to increase the understanding of Product Design and Service Design approaches in research and practice, outlining their gaps and enriching their design processes and outcomes through PSS. The study selected 10 projects: 5 using a Product Design approach and 5 using a Service Design approach. The PSS approach was also infused in the two sets of projects.

The insights collected through the multiple case study and qualitative research highlight important differences between Product Design and Service Design, in theory and in practice in particular (1) stakeholders' role, (2) design approach versus design object, (3) design space versus design context, and finally (4) materialization of solutions. Product design and Service design are important backbones of manufacturing and service industries. Understanding these approaches in theory and in practice is important to better address their gaps and improve design processes within organizations (Junginger, 2014). These results contribute to advance design research and practice, going beyond the distinction of their typical design object (product and service), uncovering multiple categories that were not clear before. These categories help distinguish Product Design and Service Design but also highlight their complementarities and may enable more synergies between the two approaches.

Study 3 also contributes to understand the design stages where PSS can be combined with Product Design and Service Design to enrich these approaches. Study results show that Product Design benefits more from the PSS at the initial stages of the design process, to acquire a broader perspective in the exploration stage, including multiple

stakeholders in problem analysis, and expand the scope of solutions co-created. Product Design typically has more focus on designing physical products, but PSS enables a broader view that expands towards interactions between different categories of stakeholders to co-create value. On the other hand, Service Design benefit from PSS at later stages of the design process enabling a more operational perspective of service solutions, emphasizing backstage and organizational processes as well as physical evidences, in a more effective way. The study contributes with important design insights that can support product and service companies to enrich their design process and create more complete solutions. The study then, responds to Baines et al. (2017) call to explore the strategies regarding PSS infusion in both product and service companies. The study identifies the stages where PSS is relevant in practice in different design context (Product Design and Service Design projects), to co-create more complete solutions.

5.4. Managerial implications

The study results also have important implications for both manufacturing and service companies. First, the S-D Logic makes the distinction between physical products and services obsolete. This perspective had yet to be embedded within PSS research, which has already been adopted in manufacturing industry (Baines et al., 2007; Baines, Lightfoot, Peppard, et al., 2009). Physical products are an important backbone of manufacturing industry, and shifting the industrial paradigm from a production to a solution-oriented mind-set requires a new vocabulary. The first study has important managerial implications as it provides a more unified language between PSS, Service Design and S-D Logic which can be further developed whenever product/service providers wish to evolve towards the new service-oriented view.

PSS has already been implemented in industry (Baines, Lightfoot, Benedettini, et al., 2009; Davies et al., 2006; Mont, 2002), but requires a more human-centered approach to improve implementation of integrated solutions. This perspective is embedded within Service Design, which already is integrated with S-D Logic (Wetter-Edman et al., 2014). The framework is the first step to create a new language to unify these design approaches to support the transition of industry toward the new service paradigm.

The second study offers an integrative PSS design approach and design models for manufacturing companies to design new product-service system solutions, balancing organizational and human-centered components of PSS and service design, respectively. The integrated PSS approach and model developed, supported a laboratory manufacturing company to leverage PSS and Service Design approaches to design new product-service system solutions for smart-labs, and define supporting organizational networks. The new PSS approach and the models were also important to support discussion between designers, as well as customers and other stakeholders of the solutions. The models enabled the participants to align efforts towards a common purpose, envisioning and defining product-service system concepts in a collaborative way and from an integrated perspective, supporting strategic design decisions along the design process and define roadmaps towards potential future business models. This co-creative effort is important, especially at the initial stages of design, where the costs of ideas and prototypes are lower, and can be tested and refined in an iterative manner.

Service concepts can be marginalized within companies as they may seem too far off the company's core business. But the PSS and Service Design integration helped to tackle this issue, by incorporating product and service components, and tailoring the multiple methods, models and tools available to better envision and systematize the design and development of integrated solutions. Moreover, the application case (study 2) showed that the models and integrated notations used were understandable for multiple stakeholders, allowing design and development teams to promptly use them. This application shows how it can be applied to real world problem and can be further used by other companies.

Finally, the results of the study 3 of the present thesis can support both manufacturing and service companies to design more complete solutions. First, it provides design insights which outline the gaps of current design approaches, namely product design and service design. This is important for companies to better understand the limitations of the approaches which are currently embedded in practice, and better prepare them to change and/or evolve. Second, the study also outlines the critical stages where PSS components can be of assistance to improve the design process and create more complete solutions, without changing the focus of Product design or Service design. This has implications for companies that want to increase their competitiveness by

designing integrated solutions for value co-creation, without changing their overall business and organizational design processes.

Overall, the thesis contributes to PSS design research and design practice as it enhances PSS infusion in companies' design processes, and improves PSS acceptance by customers by looking more into the social components of PSS with organizational aspects. It also contributes to service research as it develops and models that supports the co-creation of good-service solutions (Ostrom et al., 2015). PSS and Service Design provide a rich and unique combination to co-create new product-service system solutions. These solutions can include product artefacts, services or technologies combined to enhance customer experience, while also emphasizing the organizational perspective, to co-create value.

Moreover, the contributions presented advance PSS research and have important managerial implications, as the integrated PSS approach and models were developed with a company and practitioners to support their design activities. The approach was also infused in different design settings, namely 10 design projects using product design and service design approach. This was important to understand the improvements that partial PSS infusions can have in the design process and solutions of these projects. The thesis contributes to bridge design approaches that were not yet integrated, and also supports manufacturing and service industries to design more integrated product-service system solutions for value co-creation.

6. CONCLUSIONS

The present thesis aims to address the need to design more integrated good-service solutions. The rapid advance of technology is changing society at a very fast pace, bringing change to the nature of product and service. Failure in aligning these components at the initial stages of the design process can potentially hinder customer experience and damage companies' businesses.

We have set three objectives to deal with these challenges: (1) to explore complementarities and gaps of PSS and Service Design approaches; (2) to develop and systematize a new approach with enhanced PSS design models; and (3) to understand how PSS can be incorporated with Product Design and Service Design to enrich these approaches.

Following a design research methodology this thesis develops important contributions for design research and practice. The first paper (Costa et al., 2016) contributes to PSS design research by creating a more unified vocabulary between PSS and Service Design and S-D Logic, and develops a conceptual framework which bridges there complementarities. The second paper (Costa, Patrício, Morelli, & Magee, 2017) develops an integrative PSS approach that bridges PSS design and Service design, and supports the co-creation of new integrated solutions throughout the different stages of the design thinking process. The third paper (Costa, Patrício, Morelli, & Cressy, 2017) highlights key categories which distinguish Product Design and Service Design approaches, and contributes to better understand their perspectives regarding value co-creation. The study also identifies the stages where PSS is relevant in practice to enhance these approaches, and support the co-creation of more complete solutions.

The application in a manufacturing industry in study 2 demonstrates that the integrative PSS approach can be used in real-world settings, and is useful to solve problems and create new integrated solutions. The empirical study undertaken with 10 design projects (study 3) also demonstrates that the PSS approach can be useful to enrich the design process of companies using Product design and Service design approaches to create more integrated solutions.

The contributions of the present thesis are not without limitations. First, while PSS design as a broad range of contributions from environmental and operational management, these perspectives were not included in the development of the models. We acknowledge the needs of our current society to grow more environmentally sound solutions, and that these should be balanced with the consumption behavior theories. Since PSS have implications on customers lives, a broader socio-anthropological perspective could provide more fertile ground for exploration.

Second, the application case in a manufacturing industry can be considered to be too narrow for the methods and models to be applicable in other projects. But the multiple case studies (paper 3) have attempted to tackle this issue by presenting and embedding components of the integrated perspective within the product- and service-oriented teams' design process. For future research, the methods and models can be improved by applying them in other projects, within either manufacturing or service industries. Also, the models were evaluated by the design team through a workshop and questionnaire. However providing added validation would require enlarging significantly the number of people exposed to the method and models.

Third, the multiple case studies presented in paper (3) was undertaken within an educational environment, in collaboration with companies. The contributions and managerial implications could be richer if the approach was embedded within multiple organizational environments, where design and development teams have access to more resources (e.g. materials, time etc.), and could iterate more often to reach a fuller and more satisfying design solution.

This thesis contributes to research priorities of service research (Ostrom et al., 2015) and PSS research (Baines, Bigdeli, & Bustinza, 2017), namely the ones regarding the need to support the design of more integrated good-service solutions for value co-creation. It brings to PSS design research a framework, as well as a new method and models that bridge PSS organizational-network view, with the more holistic and human-centered approach of Service design. This multidisciplinary combination has managerial implications since the artifacts and design insights developed can be used by manufacturing and service industries to support their design activities, acquiring a

broader perspective of problems, and co-creating more integrated solutions for their customers.

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